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GSAT-11

CONFIGURATION SUMMARY

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ISRO Satellite Centre

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1 Introduction

1.1 Mission Objective

With the existing I1K, I2K & I3K buses of ISRO being operational, there is a requirement to develop a new generation bus capable of meeting present day requirements. A new I6K bus is developed by ISRO. The bus can support lift off mass of 4 tons to 6tons to support mission life of a typical of 15 years.

GSAT-11 is the first spacecraft developed on the new I-6K platform. This spacecraft will meet the demand of high throughput and a large capacity payload platform to support a huge subscriber base of VSAT class of terminals. This spacecraft will provide broadband system solutions and will also provide telecommunication & multimedia serials to household, business & public organization.

Sufficient redundancy is built in the Spacecraft for continued service. All components are designed with adequate margin to provide nominal mission life of 15 years. The orbital location for GSAT-11 spacecraft is 74^0 E.

The key features of GSAT-11 Spacecraft is given in Table 1.1

Table 1.1 Key features of spacecraft

Subsystem Element	Spacecraft configuration
Payload	• **Communication Payload:** ✓ 32 Ka x Ku band forward link transponders. ✓ 8 Ku x Ka Band Return link transponders. ✓ Effective bandwidth of 4 GHz each in uplink and downlink using 4 colour frequency reuse and 2 times polarization reuse ✓ 32 user beams each of 125 MHz (usable BW:116 MHz) ✓ Four hub beams each 1 GHz, each hub beam cater to 8 user beams ✓ ka x ka direct link between western and southern hub beams ✓ Dynamic power sharing among 4 user beams in MPA configuration • **Antenna:** ✓ 2 nos of Ku band deployable reflectors of 2 m with close loop RF tracking ✓ 1 no. Fixed EV top antenna for Ka band of 1.4 m
Structure	• I-6K platform with cuboid dimension of 2210 mm (E-W) x 2113 mm (N-S) x

	4863 mm (EV-AEV). • Independent Bus module, Payload module and propulsion modules
Thermal	• Conventional thermal management with embedded heat pipes in North, South and EV panel and surface heat pipes for ID-1 and Battery panels • Heater: 256 nos. (Includes both Main & Redundant) • Thermistors: Mainframe: 204, Payload: 200 • PRTs: Mainframe: 57, Payload: 23 (NIN-10 can process upto 90 PRTs)
Mechanisms	• Solar Array Deployment mechanism: o 2 wings of solar array with 5 panels on each wing. o 'T' shaped solar array and 'T' Yoke configuration o No. of Hold downs : 8 Nos for each wing • Antenna deployment mechanisms: o Reflector Hold Down and Release Mechanism to support Reflector for launch loads o 2 Axis Deployment and Pointing Mechanism (DPM) to deploy and perform pointing function in two axes. o Two Antenna on East and Two antenna on West
Propulsion	• Standard Bi-propellant Chemical propulsion system for both orbit raising and attitude maintenance • Two numbers of 1450L propellant tanks for Ox and Fuel • 3 no. of pressurant tanks each of 67 litre • 250 AR LAM with 70V valves • 8 nos of 22N and 8 nos of 10N thrusters with 70V Valves • Five numbers of conventional pressure transducers **Configuration change post CDR:** • Two numbers of Single flow latch valves (SFLV Ox and SFLV Fu) and one number of conventional LVG in place of 4 no. Of SFLVs in Ox and Fu path. • Addition of one pyro valve NCG4 in the pressure regulator bypass path. • Addition of one pressure transducer in the downstream of Pressure Regulator PR1.
Composite	• Bigger size solar panel substrate (10 nos) – 3.3 m x 2.1 m each • 'T' shape yoke (2 nos) • SADA Cone (2 nos) • 2 m single shell parabolic Ku band deployable reflectors (4 nos) • 1.4 m offset Ka band reflector (1 no)

Power	• 70V fully regulated single bus, regulated by FS3R during sunlit and Battery/BDR during eclipse • 2 no. of 180Ah Li-ion battery (SAFT, France) mounted on east and west side • 10 solar panels each of size 3.3 m x 2.1 m & power generation of ~14KW • Power Electronics: ✓ Two Core Power Electronics package ✓ Two BDR packages with 6 BDR modules, 1 SS module ✓ Two shunt packages with 7 modules each ✓ Six Fuse Distribution Modules ✓ Two Battery current sensor ✓ Two payload current sensor ✓ Two EED Powering units • Power distribution through imported Bus bar • HK bus bar (2 no) • Payload bus bar (6 Nos of 1 m length each connected with flexible briad) **Configuration changes post CDR** • Addition of Two no. of Current sensor Reset box
TTC-BB	• CCSDS based TM/TC system, TC uplink : 500bps, PCM/PSK/FM, TM downlink : 2 kbps, PCM/PSK/PM • TMTC core package (2 nos) for command distribution to mainframe elements • Payload interface package (1 no) for command distribution to payload elements • 1553B interface for telemetry and telecommand with all the subsystems through dual bus configuration of TC and AOCE 1553 bus • Isolated interfaces for direct telecommand and differential interfaces for direct telemetry. **Configuration changes post CDR** • Addition of an external LDO package in series with the internal LDO
TTC-RF	• C band TTC-RF system • 2 nos of TTC-Rx • 2 nos of TTC-Tx • Omni antenna (EV and AEV) and global horn antenna • Ku band beacon modulator (for 3rd level redundancy of the TM)
AOCS	• Momentum biased system with 2 Momentum wheels of 68 Nms and 1 Transverse Momentum wheel of 28 Nms. • Pointing requirement: Yaw (±0.2°), Roll (±0.15°), Pitch (±0.15°) • Close loop antenna RF tracking to achieve desired antenna pointing

	requirement of ±0.05º in multi beam scenario • 2 no. of AOCE packages (M & R) • 2 no. of Antenna Drive Electronics (ADE) to drive 4 DPMs • 2 no. of Tracking Rx interface package (TRRT) for providing 1553 interface between tracking Rx and AOCE • 1553B interface for all sensors • 2 nos of Magnetic torquer of $350Am^2$
Sensors	• 2 no. of Star sensors with 1 no. of Attitude processing unit(APU) and 2 no. of Camera Head Units (CHUs) • 2 no. of ES • 2 no. of APSS • 1 no of sensor electronics package (N4IN10) • 4 no. of SPSS, 4 no. of conventional CASS, 4 no. of micro-CASS • 1553B interface for all the sensor elements, 70V Indigenous DC-DC converters for all elements **Configuration changes post CDR** • Use of two Star sensor (1 APU, 2 CHUs) in place of four star sensors (1 APU, 4 CHUs)
IISU elements	• 1 no of conventional IRU-400 • 2 no. of unified SADE and 2 no. of SADA mechanisms • 1 no of Ceramic Servo Accelerometer Package (CSAP) for delta-V measurement during LAM and NSSK operations • All elements with 1553 interfaces and 70V M3G converters

Description of sub systems is detail is provided in chapter-2 to 14.

The deployed and stowed views of GSAT-11 spacecraft are shown in figures 1.1 & 1.2.

Figure 1.1 Deployed view of the spacecraft

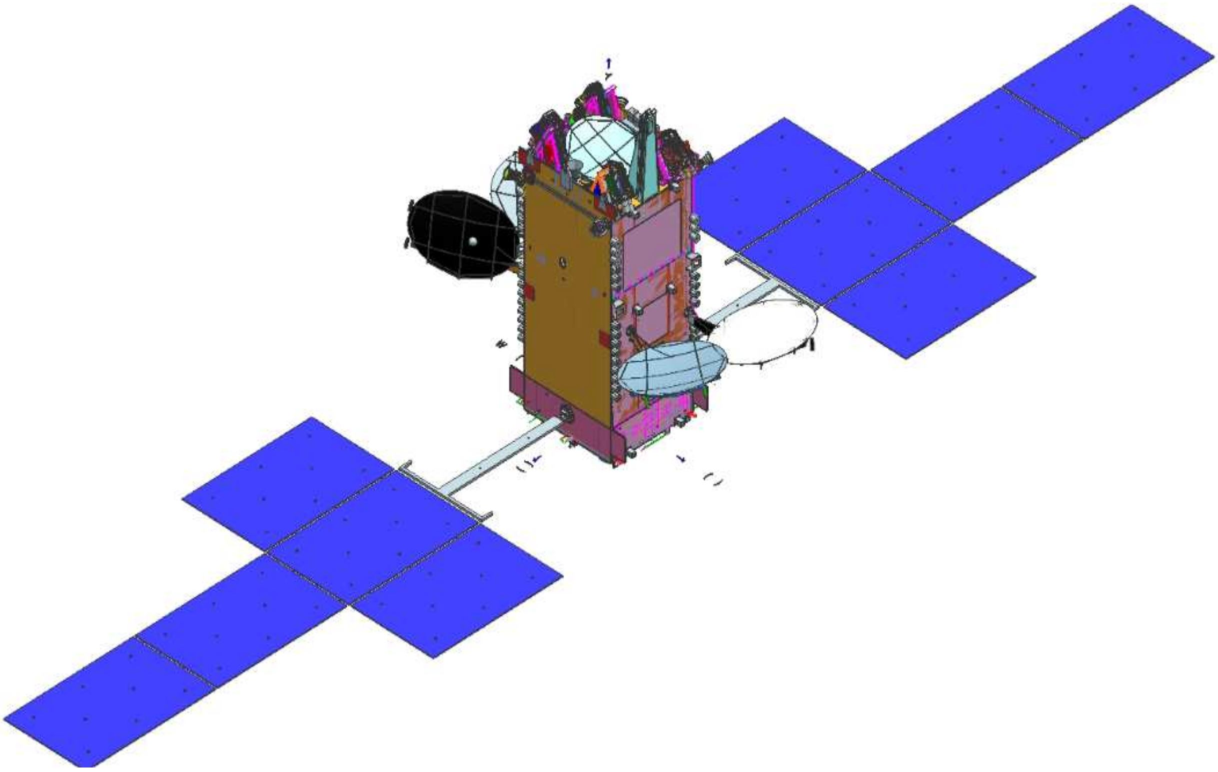
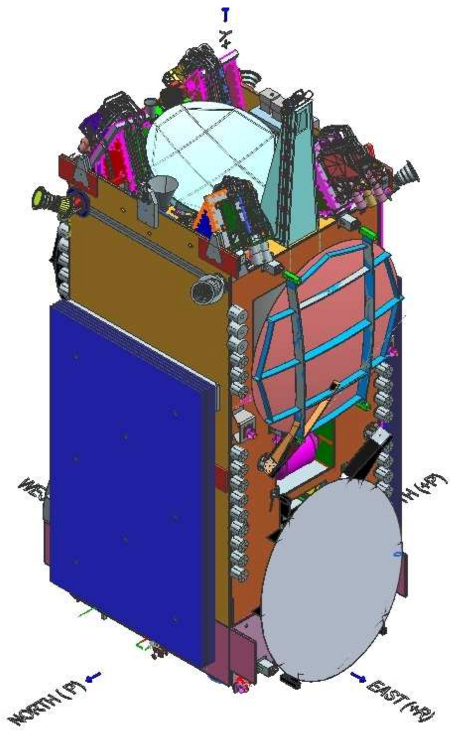


Figure 1.2 Stowed view of the spacecraft



2 Communication Payload

2.1 Introduction

GSAT-11 is configured with multi-beam communication payload to cater to the Fixed Satellite Services (FSS) over Indian mainland and Islands. The satellite is having Ka x Ku band and Ku x Ka band transponders in bent-pipe configuration, which provide fixed satellite services to multiple users through star-based configurations.

The main features of GSAT-11 Communication payload are as follows:

- 32 user spot beams operating in Ku band
- 8 Hub beams operating in Ka band
- A tracking system shared among 4 Ku band reflectors for maintaining the desired pointing accuracy.
- A switchable ka x ka direct link between the western hub beam and the southern hub beam
- 4 of the ka x ku band transponders are configured in Multi Port Amplifier (MPA) configuration for dynamic power sharing among 4 of the user beams.
- Two no. of Ku band beacon (in orthogonal polarisation) and two no. of Ka-band beacon (in orthogonal polarisation).

2.2 Operational Requirements

GSAT-11 to be located at 74 deg East is a multi-beam communication payload configured to cater to the Fixed Satellite Services (FSS) over Indian mainland and Islands. The satellite is having Ka x Ku band and Ku x Ka band transponders in bent-pipe configuration, which provide fixed satellite services to multiple users through star-based configurations.

The forward link is defined from gateway to user terminal via Ka x Ku channels. The return link is defined from user terminal to hub via Ku x Ka channels.

The payload shall provide a total of 40 transponders channels out of which:

- Thirty-two forward link (Ka x Ku) transponders, operating in the 30 GHz uplink and 11 GHz downlink.

- Eight return link transponders, operating in 13 GHz uplink and 20 GHz downlink.

The Transponder configuration diagram with Ka x Ku & Ku x Ka payload chains is shown in Figure 2-2 to Figure 2-7.

Payload is configured with a Tracking system which will be shared among the four Ku-band reflector systems for maintaining the desired pointing accuracy. Figure 2-6 provides the block schematic of tracking system. The signal for tracking system will be uplinked from four identified stations from ground.

Payload is also configured with a switchable Ka x Ka-band direct link between Western and Southern hub beam (connectivity shown in Figure 2-2 and Figure 2-4).

Four of the Ka x Ku transponders are configured in Multiport Amplifier configuration (shown in Figure 2-2) for dynamic sharing of power among four of the user beams.

Figure 2-7 shows the antenna Interface diagram with the payload.

2.3 Frequency Plan

The payload shall operate in the frequency bands given below in Table 2-1.

Table 2-1: Spectrum Utilization

Transponder	Uplink (MHz)	Downlink (MHz)
Ka x Ku (Forward Link)	29500-30000 In both LH & LV	10700 – 10950, 11200 - 11450 In LH & LV
Ku x Ka (Return Link)	12750 - 13250 In LH & LV	19700 – 20200 In both LH & LV
Ka x Ka (Switchable Link)	29500 – 29750 in LV	19700 – 19950 in LH

The individual Beam plan with frequency allocation shall be as per Table 2-4 and

Channel No.	Ku-beam	Channel	Uplink		Downlink		Usable BW (MHz)
		Designation	Centre freq (MHz)	Pol.	Centre freq (MHz)	Pol.	

1	B1	Ka8 x Ku1	29812	L-V	11262	L-H	116
2	B2	Ka5 x Ku2	29687	L-V	10887	L-H	116
3	B3	Ka7 x Ku3	29562	L-V	10762	L-H	116
4	B4	Ka8 x Ku4	29937	L-V	11387	L-H	116
5	B5	Ka6 x Ku5	29812	L-V	11262	L-H	116
6	B6	Ka8 x Ku6	29687	L-V	10887	L-H	116
7	B7	Ka8 x Ku7	29562	L-V	10762	L-H	116
8	B8	Ka5 x Ku8	29937	L-V	11387	L-H	116
9	B9	Ka5 x Ku9	29812	L-V	11262	L-H	116
10	B10	Ka6 x Ku10	29687	L-V	10887	L-H	116
11	B11	Ka6 x Ku11	29562	L-V	10762	L-H	116
12	B12	Ka6 x Ku12	29937	L-V	11387	L-H	116
13	B13	Ka7 x Ku13	29812	L-V	11262	L-H	116
14	B14	Ka7 x Ku14	29687	L-V	10887	L-H	116
15	B15	Ka5 x Ku15	29562	L-V	10762	L-H	116
16	B16	Ka7 x Ku16	29937	L-V	11387	L-H	116
17	B17	Ka4 x Ku17	29812	L-H	11262	L-V	116
18	B18	Ka1 x Ku18	29687	L-H	10887	L-V	116
19	B19	Ka3 x Ku19	29562	L-H	10762	L-V	116
20	B20	Ka4 x Ku20	29937	L-H	11387	L-V	116
21	B21	Ka2 x Ku21	29812	L-H	11262	L-V	116
22	B22	Ka4 x Ku22	29687	L-H	10887	L-V	116
23	B23	Ka4 x Ku23	29562	L-H	10762	L-V	116
24	B24	Ka1 x Ku24	29937	L-H	11387	L-V	116
25	B25	Ka1 x Ku25	29812	L-H	11262	L-V	116
26	B26	Ka2 x Ku26	29687	L-H	10887	L-V	116
27	B27	Ka2 x Ku27	29562	L-H	10762	L-V	116
28	B28	Ka2 x Ku28	29937	L-H	11387	L-V	116
29	B29	Ka3 x Ku29	29812	L-H	11262	L-V	116
30	B30	Ka3 x Ku30	29687	L-H	10887	L-V	116
31	B31	Ka1 x Ku31	29562	L-H	10762	L-V	116
32	B32	Ka3 x Ku32	29937	L-H	11387	L-V	116

Table 2-5.

An illustration of the frequency bands exploited in GSAT-11 system is shown in Figure 2-1 . The arrows represent the nominal uplink-to-downlink frequency band mappings.

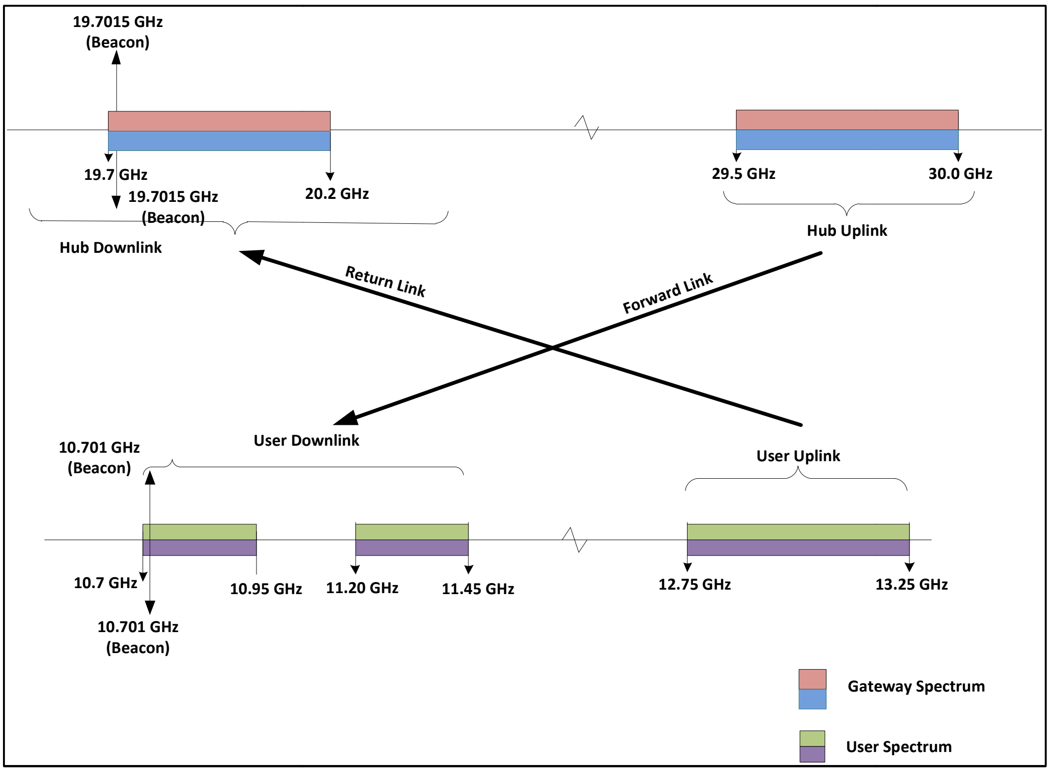


Figure 2-1 System Frequency Plan

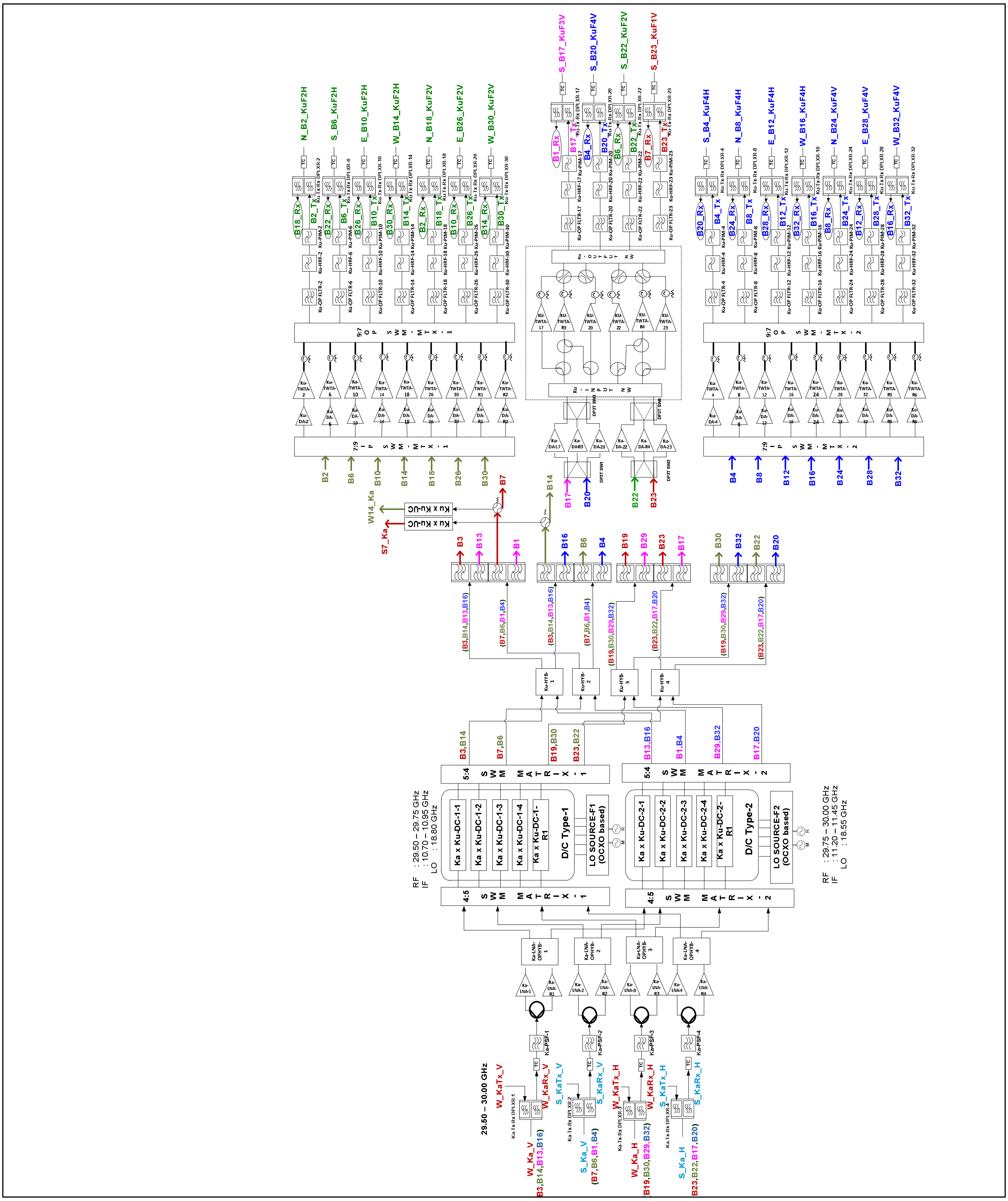


Figure 2-2 Ka x Ku Forward Link-1

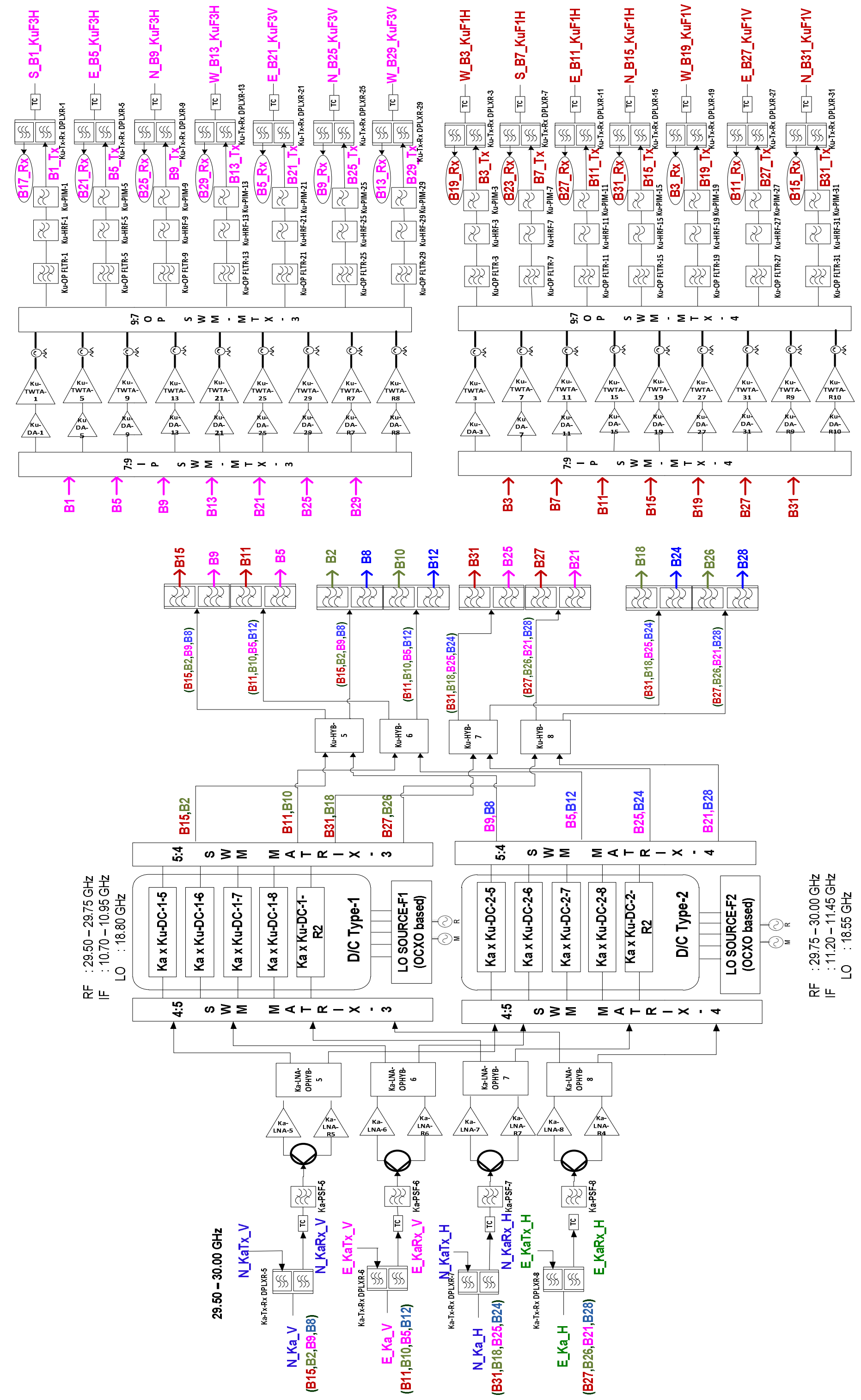


Figure 2-3 Ka x Ku Forward Link-2

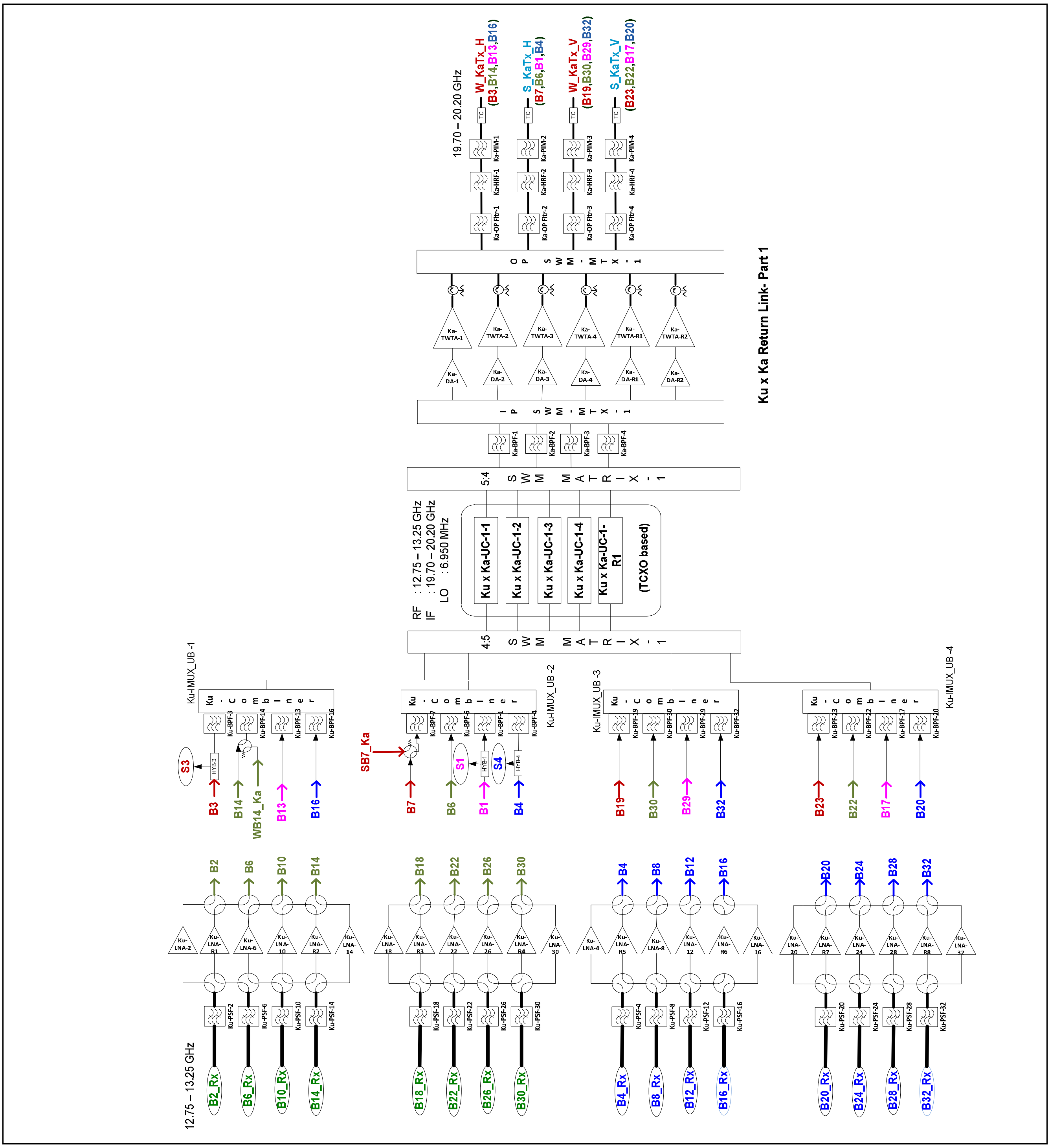


Figure 2-4 Ku x Ka Return Link-1

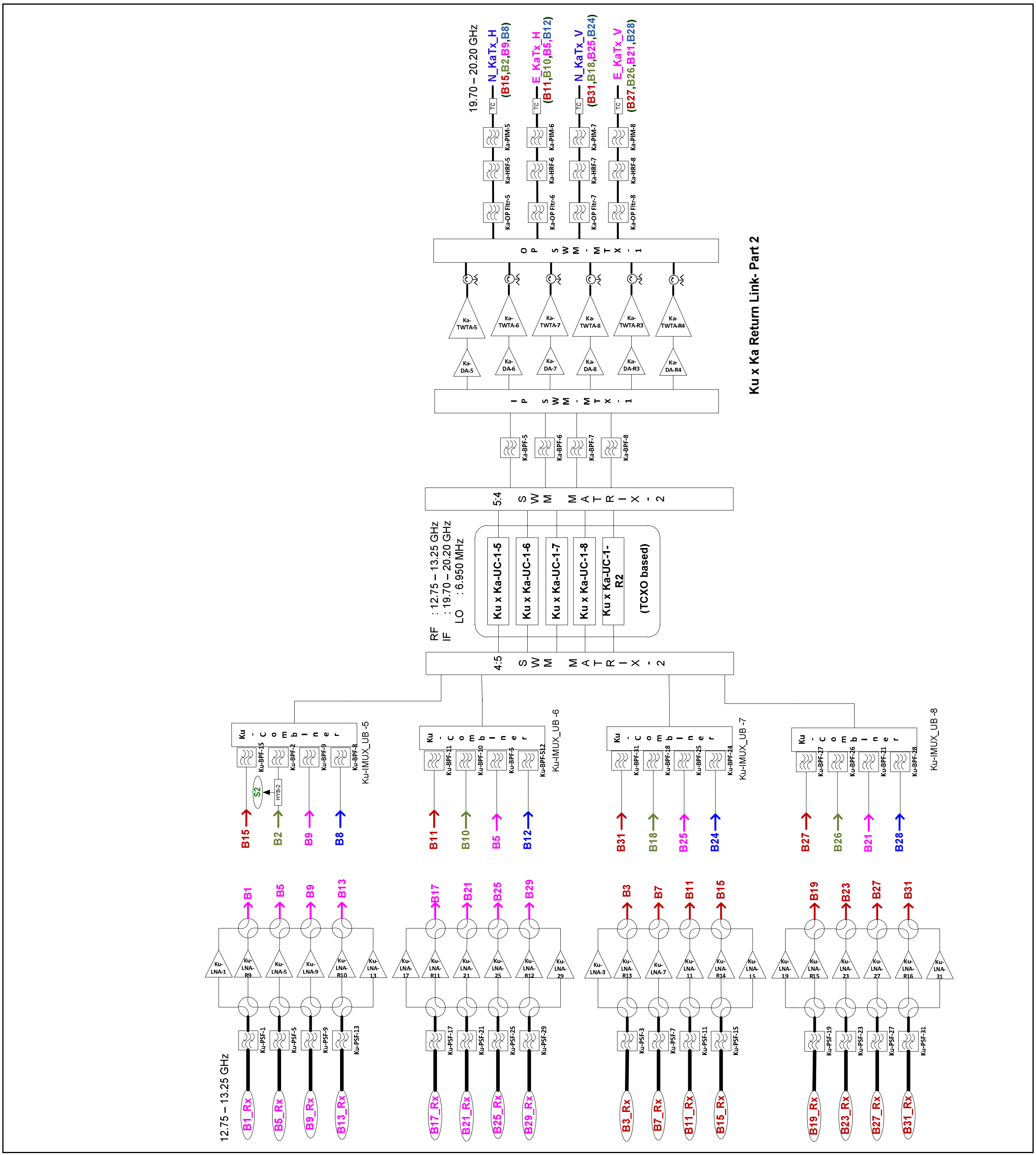


Figure 2-5 Ku x Ka Return Link-2

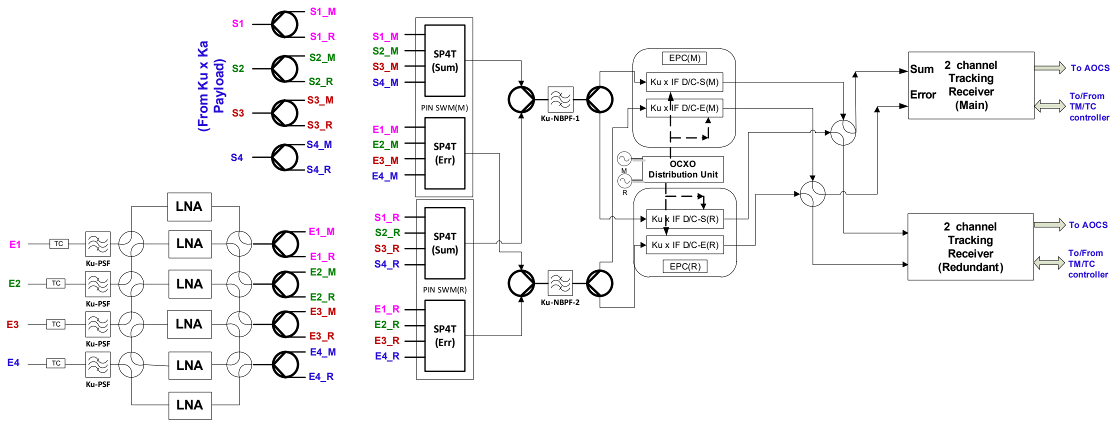


Figure 2-6 Tracking System Configuration

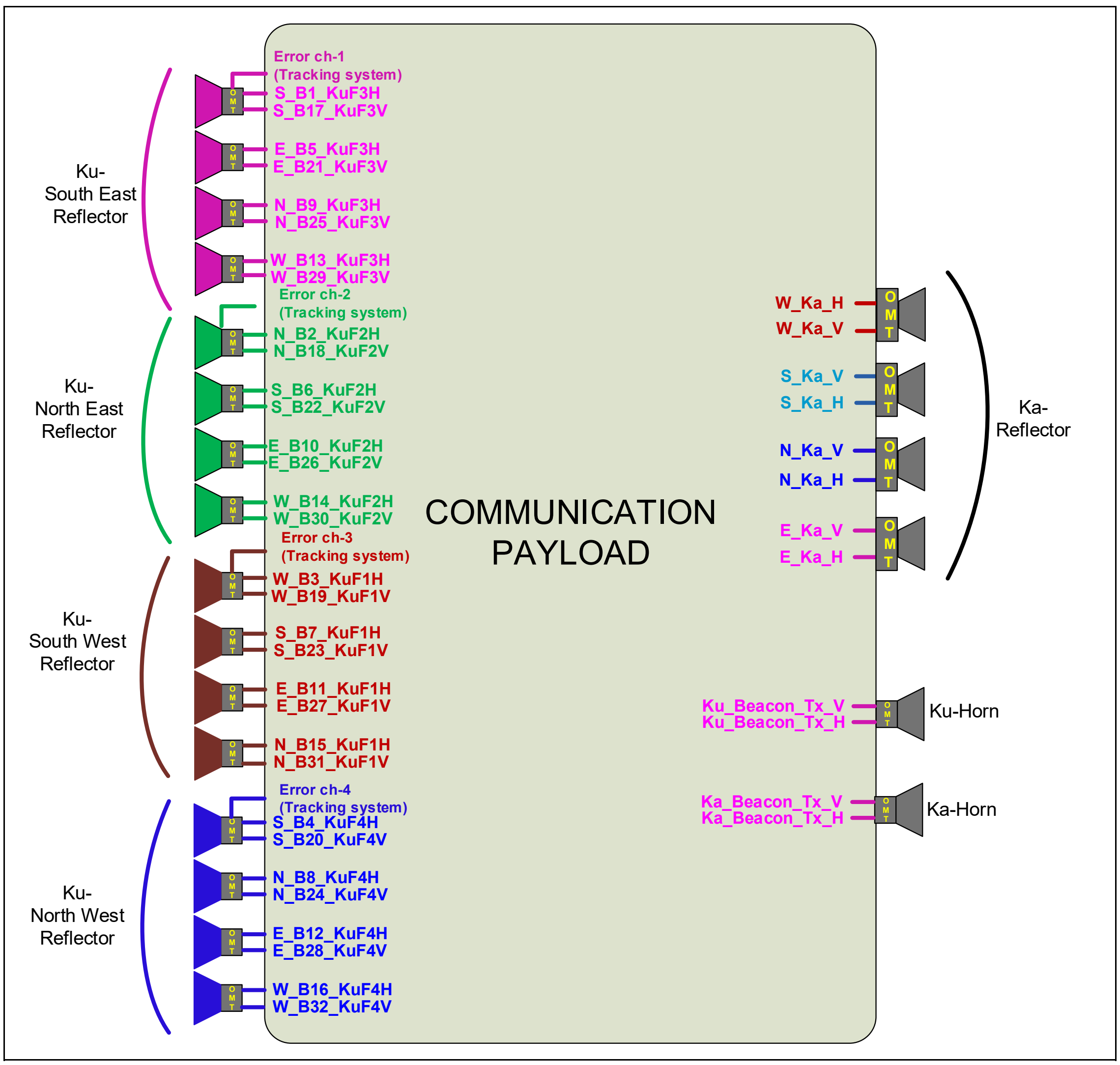


Figure 2-7 Antenna Interface Configuration

2.3.1 User Spectrum

The user uplink and downlink frequencies are (as shown in Figure 2-1) in Ku-band, uplink being 12750 to 13250 MHz and downlink 10700 to 10950 & 11200 to 11450 MHz, utilizing a total band of 500 MHz in uplink as well as in downlink. Effective spectrum of 4 GHz is generated in both Uplink and Downlink frequency bands through 4 color frequency reuse and 2 times polarization reuse.

2.3.2 Hub Spectrum

Each hub is connected with eight user beams (four beams in one polarization + overlying four beams in orthogonal polarization). As shown in Figure 2-1, the uplink and downlink frequencies for hub operations are in Ka-band, uplink being 29500 -30000 MHz and downlink of 19700 – 20200 MHz utilizing a total band of 500 MHz in uplink as well as in downlink. Through the frequency reuse of 4 times and also polarization reuse, the effective BW becomes 4 GHz each in Uplink and Downlink frequency bands.

2.3.3 Uplink Beacon Frequency (Tracking)

Uplink Beacon frequency identified for On-board Antenna tracking system is 12750 MHz in Right Hand Circular Polarization (RHCP). This beacon signal will be up-linked from identified beacon uplink stations located in four beams (i.e. Ku1, Ku2, Ku3 and Ku4).

2.4 Service Coverage Area

GSAT-11 spacecraft with 32 spot beams in Ku-band incorporated frequency reuse and polarization reuse scheme to increase frequency spectrum utilization efficiency. The coverage requirement shall be met for all antenna beam-pointing errors as specified in this document.

Gateway beams in Ka-band named as ‘Ka1’ to ‘Ka4’ represent coverage for Uplink/Downlink in Horizontal polarization. For coverage in the orthogonal polarization i.e in Vertical polarization, corresponding beams are ‘Ka5’ to ‘Ka8’. Thus beam ‘Ka5’ will overlay with beam ‘Ka1’ and so on.

Similarly, beams named as ‘B1’ to ‘B16’ represent Ku-Band Coverage Uplink Vertical/Downlink Horizontal polarization. For coverage in the orthogonal polarization i.e. Uplink Horizontal/Downlink Vertical, corresponding beams are ‘B17’ to ‘B32’. Thus beam ‘Ku17’ will overlay with beam ‘Ku1’ and so on.

The Transmit and Receive antennas shall have radiation patterns such that all the communication performance specifications shall be met over the service area. The coverage boundary for the service area is defined as follows.

- **Ka-Band Coverage:** 4 spot beams over Indian Main land region in each polarization.

- **Ku-band Coverage:** 14 spot beams to cover Indian Mainland and 1 beam each for Andaman Nicobar and Lakshadweep islands in each polarization.

Table 2-2: Forward Link (Ka x Ku) beam Association

Ka-band		Ku-beams	
Beam No.	**Uplink Polarization**	**Beam No.**	**Downlink polarization**
Ka5	Linear–V	B15, B2, B9, B8	Linear–H
Ka6	Linear–V	B11, B10, B5, B12	Linear–H
Ka7	Linear–V	B3,B14, B13, B16	Linear–H
Ka8	Linear–V	B7, B6, B1, B4	Linear–H
Ka1	Linear–H	B31, B18, B25, B24	Linear–V
Ka2	Linear–H	B27, B26, B21, B28	Linear–V
Ka3	Linear–H	B19, B30, B29, B32	Linear–V
Ka4	Linear–H	B23, B22, B17, B20	Linear–V

Table 2-3: Return Link (Ku x Ka) beam association

Ku-band		Ka-band	
Beam Sharing the same Transponder For Ku x Ka Payload	**Uplink Polarization**	**Beam No.**	**Downlink Polarization**
B15, B2, B9, B8	Linear–V	Ka1	Linear–H
B11, B10, B5,B12	Linear–V	Ka2	Linear–H
B3,B14, B13, B16	Linear–V	Ka3	Linear–H
B7, B6, B1, B4	Linear–V	Ka4	Linear–H
B31, B18, B25, B24	Linear–H	Ka5	Linear–V
B27, B26, B21, B28	Linear–H	Ka6	Linear–V
B19, B30, B29, B32	Linear–H	Ka7	Linear–V
B23, B22, B17, B20	Linear–H	Ka8	Linear–V

2.4 Frequency Channelization Plan

Ku-band frequencies will be repeated 4 times due to 4 colour reuse and Ka-band frequencies will be repeated 4 times due to 4 times reuse. Ku-band and Ka-band will utilize 500 MHz spectrum in each polarization. Frequency Channelization plan for the Ka x Ku and Ku x Ka transponders is shown in Table 2-4 and
Table 2-5.

Table 2-4: Forward Link (Ka x Ku) Frequency Channelization Plan

Channel No.	Ku-beam	Channel	Uplink		Downlink		Usable BW (MHz)
		Designation	Centre freq (MHz)	Pol.	Centre freq (MHz)	Pol.	
1	B1	Ka8 x Ku1	29812	L-V	11262	L-H	116
2	B2	Ka5 x Ku2	29687	L-V	10887	L-H	116
3	B3	Ka7 x Ku3	29562	L-V	10762	L-H	116
4	B4	Ka8 x Ku4	29937	L-V	11387	L-H	116
5	B5	Ka6 x Ku5	29812	L-V	11262	L-H	116
6	B6	Ka8 x Ku6	29687	L-V	10887	L-H	116
7	B7	Ka8 x Ku7	29562	L-V	10762	L-H	116
8	B8	Ka5 x Ku8	29937	L-V	11387	L-H	116
9	B9	Ka5 x Ku9	29812	L-V	11262	L-H	116
10	B10	Ka6 x Ku10	29687	L-V	10887	L-H	116
11	B11	Ka6 x Ku11	29562	L-V	10762	L-H	116
12	B12	Ka6 x Ku12	29937	L-V	11387	L-H	116
13	B13	Ka7 x Ku13	29812	L-V	11262	L-H	116
14	B14	Ka7 x Ku14	29687	L-V	10887	L-H	116
15	B15	Ka5 x Ku15	29562	L-V	10762	L-H	116
16	B16	Ka7 x Ku16	29937	L-V	11387	L-H	116
17	B17	Ka4 x Ku17	29812	L-H	11262	L-V	116
18	B18	Ka1 x Ku18	29687	L-H	10887	L-V	116
19	B19	Ka3 x Ku19	29562	L-H	10762	L-V	116
20	B20	Ka4 x Ku20	29937	L-H	11387	L-V	116
21	B21	Ka2 x Ku21	29812	L-H	11262	L-V	116
22	B22	Ka4 x Ku22	29687	L-H	10887	L-V	116
23	B23	Ka4 x Ku23	29562	L-H	10762	L-V	116
24	B24	Ka1 x Ku24	29937	L-H	11387	L-V	116
25	B25	Ka1 x Ku25	29812	L-H	11262	L-V	116
26	B26	Ka2 x Ku26	29687	L-H	10887	L-V	116

27	B27	Ka2 x Ku27	29562	L-H	10762	L-V	116
28	B28	Ka2 x Ku28	29937	L-H	11387	L-V	116
29	B29	Ka3 x Ku29	29812	L-H	11262	L-V	116
30	B30	Ka3 x Ku30	29687	L-H	10887	L-V	116
31	B31	Ka1 x Ku31	29562	L-H	10762	L-V	116
32	B32	Ka3 x Ku32	29937	L-H	11387	L-V	116

Table 2-5: Return Link (Ku x Ka) Frequency Channelization Plan

Channel No.	Ku-beam	Channel Designation	Uplink		Downlink		Usable BW (MHz)
			Centre freq (MHz)	Pol.	Centre freq (MHz)	Pol.	
33	B1	Ku17 x Ka4	13062	L-V	20012	L-H	116
34	B2	Ku18 x Ka1	12937	L-V	19887	L-H	116
35	B3	Ku19 x Ka3	12812	L-V	19762	L-H	116
36	B4	Ku20 x Ka4	13187	L-V	20137	L-H	116
37	B5	Ku21 x Ka2	13062	L-V	20012	L-H	116
38	B6	Ku22 x Ka4	12937	L-V	19887	L-H	116
39	B7	Ku23 x Ka4	12812	L-V	19762	L-H	116
40	B8	Ku24 x Ka1	13187	L-V	20137	L-H	116
41	B9	Ku25 x Ka1	13062	L-V	20012	L-H	116
42	B10	Ku26 x Ka2	12937	L-V	19887	L-H	116
43	B11	Ku27 x Ka2	12812	L-V	19762	L-H	116
44	B12	Ku28 x Ka2	13187	L-V	20137	L-H	116
45	B13	Ku29 x Ka3	13062	L-V	20012	L-H	116
46	B14	Ku30 x Ka3	12937	L-V	19887	L-H	116
47	B15	Ku31 x Ka1	12812	L-V	19762	L-H	116
48	B16	Ku32 x Ka3	13187	L-V	20137	L-H	116
49	B17	Ku1 x Ka8	13062	L-H	20012	L-V	116
50	B18	Ku2 x Ka5	12937	L-H	19887	L-V	116
51	B19	Ku3 x Ka7	12812	L-H	19762	L-V	116
52	B20	Ku4 x Ka8	13187	L-H	20137	L-V	116
53	B21	Ku5 x Ka6	13062	L-H	20012	L-V	116
54	B22	Ku6 x Ka8	12937	L-H	19887	L-V	116
55	B23	Ku7 x Ka8	12812	L-H	19762	L-V	116
56	B24	Ku8 x Ka5	13187	L-H	20137	L-V	116

57	B25	Ku9 x Ka5	13062	L-H	20012	L-V	116
58	B26	Ku10 x Ka6	12937	L-H	19887	L-V	116
59	B27	Ku11 x Ka6	12812	L-H	19762	L-V	116
60	B28	Ku12 x Ka6	13187	L-H	20137	L-V	116
61	B29	Ku13 x Ka7	13062	L-H	20012	L-V	116
62	B30	Ku14 x Ka7	12937	L-H	19887	L-V	116
63	B31	Ku15 x Ka5	12812	L-H	19762	L-V	116
64	B32	Ku16 x Ka7	13187	L-H	20137	L-V	116

Table 2-6: Ka x Ka (Switchable) Frequency Channelization Plan

Channel No.	Channel Designation	Uplink		Downlink		Usable BW (MHz)
		Centre Freq (MHz)	Pol.	Centre Freq (MHz)	Pol.	
7/46	Ka8 x Ka3	29562	L-V	19887	L-H	116
14/39	Ka7 x Ka4	29687	L-V	19762	L-H	116

Note *:" Channel Designation" may be read as "Uplink Freq. band & Associated Coverage Beam number x Downlink Freq. Band & Associated Coverage Beam number ". Thus, e.g. Ka1 x Ku15 indicates a channel that operates with uplink in Ka-Band through Beam No.1 and downlink in Ku-Band through Beam No. 15.

Table 2-7:Ground Beacon Transmitter Frequency

Beacon	Transmit Frequency (MHz)	Polarization
Ku-band Ground Beacon (for On-Board Tracking System)	12750	RHCP

2.6 On-board Power Sharing

Four of the User Beams i.e. B17, B20, B22 and B23 in Ka x Ku Forward link are configured in Multiport Amplifier configuration to share the power among them. These beams shall be controlled by Ka4 Hub.

2.7 Polarization

2.7.1 Ka-Band

The uplink and down link signals in Ka-Band shall operate in the linear polarization. The sense of polarization will be as defined below:

Receive : 29500 – 30000 MHz (Linear Vertical & Linear Horizontal)

Transmit : 19700 – 20200 MHz (Linear Vertical & Linear Horizontal)

2.7.2 Ku-Band

The uplink and down link signals in Ku-Band shall operate in the linear polarization. The sense of polarization will be as defined below:

Receive : 12750 – 13250 GHz (Linear Vertical & Linear Horizontal)

Transmit : 10700 – 10950 MHz, 11200 – 11450 MHz (Linear Vertical & Linear Horizontal)

Notes:

Receive E field vector shall be Vertical, defined as being parallel to the spacecraft's nominal pitch axis.

Transmit E field vector shall be Horizontal, defined as being parallel to the spacecraft's nominal roll axis.

2.8 Ku-Band Beacon Transmitter Performance Requirements

A total of four Beacon Transmitters, two in Ku-band and two in Ka-band are configured in GSAT-11 Payload. Figure 2-8 shows the Beacon Transmitter configuration. The Payload is equipped with two Ka-band Beacons (in orthogonal polarization) and two Ku-band Beacons (in orthogonal polarization).

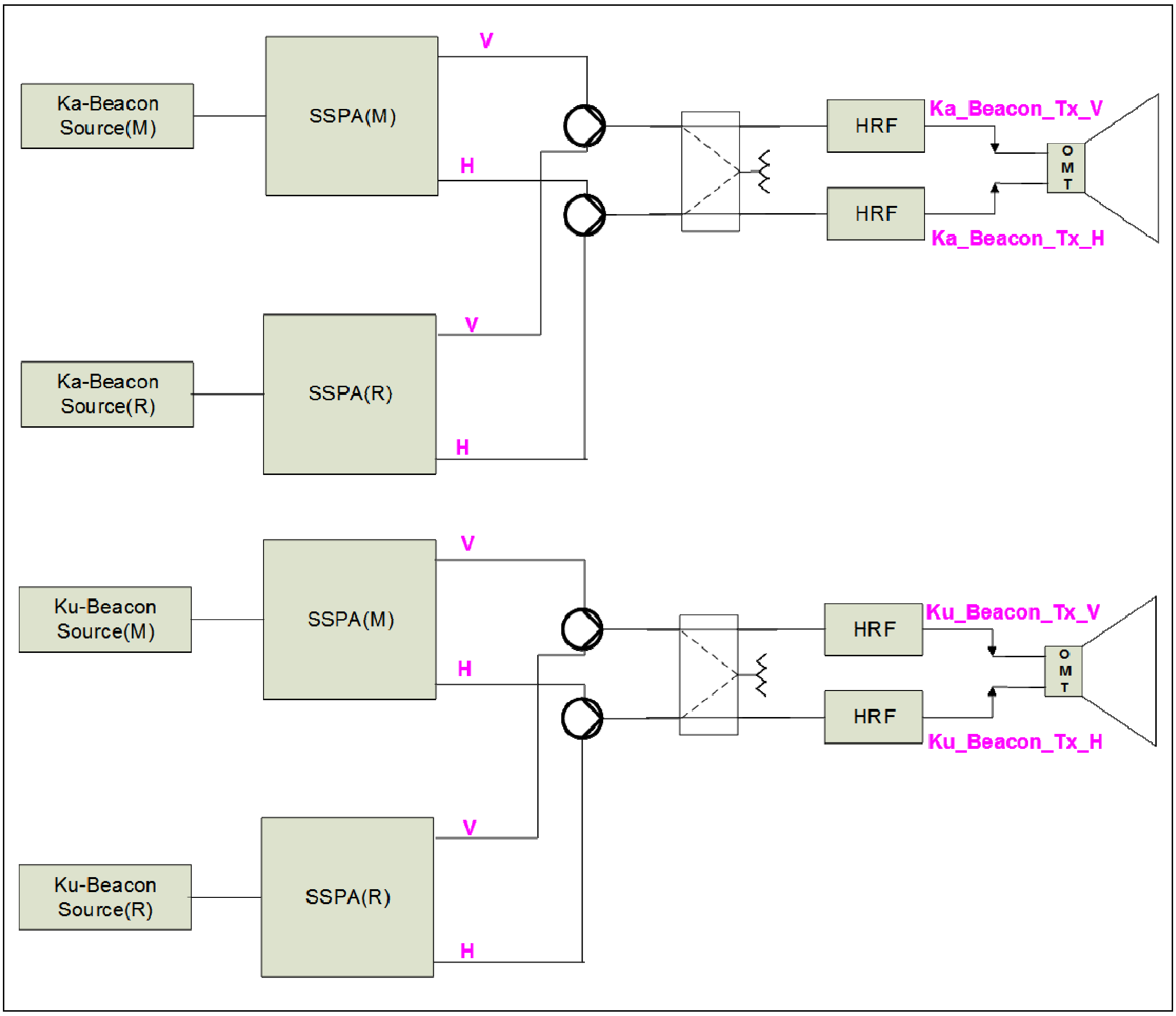


Figure 2-8 Beacon Transmitters

2.8.1 Frequency Plan and Polarization

Frequency plan and polarization of on-board beacon transmitters are given in the Table 2-8.

Table 2-8 : Frequency Plan for Beacon Transmitters

On Board Beacon Transmitter No.	Frequency (MHz)	Polarization
Ku-B1	10701.0	Linear – H
Ku-B2	10701.0	Linear – V
Ka-B1	19701.5	Linear – H

Ka-B2	19701.5	Linear – V

2.8.2 Coverage

The Ka and Ku-band Beacon transmit beam shall have India Mainland coverage, A&N and Lakshadweep Islands coverage.

2.9 Transmit EIRP

Ka-Beacon

The transmitter shall provide a Beacon EIRP of 21 dBW over lifetime at the edge of India Mainland coverage and A&N and Lakshadweep Islands.

Ku-Beacon

The transmitters shall provide a Beacon EIRP of 21 dBW over lifetime at the edge of India Mainland coverage and A&N and Lakshadweep Islands.

3 Spacecraft Structures

3.1 Introduction

GSAT-11 spacecraft structure is the new I-6K Spacecraft bus which is designed for 6500 kg Lift Off Mass. All the interfaces of GSAT-11 spacecraft structure are compatible with GSLV MK-III and commercial launch vehicles.

3.2 Structure Configuration

I-6K bus structure is a cuboid of size 2210 mm (E-W) x 2113 mm (N-S) x 4863 mm (EV-AEV). It is in three modules: bus modules, propulsion module and payload module. The payload module can be assembled to the bus module after all payload integration and tests are over.

The bus module structure consists of

- ✓ Interface ring
- ✓ Bottom cylinder
- ✓ AEV deck
- ✓ Intermediate deck-1
- ✓ Battery decks (on East & West)
- ✓ House Keeping panels (on North and South)
- ✓ Propulsion decks.

The Bus module accommodates Propellant tanks, Pressurant tanks, Momentum wheels, LAM, Bus electrical systems, Propulsion component module. The main cylinder permits accommodation of two large cassini propellant tanks of upto 1450 litre capacity. The SADA is located on the HK panel and the hold-downs of the arrays are located on the north and south decks. The stowed yoke is of a full panel length.

The payload module structure consists of

- ✓ Top cylinder
- ✓ North and South equipment (payload) panels,
- ✓ Earth-view (EV) panel,
- ✓ Intermediate Deck (ID-2), and
- ✓ Associated shear webs

The north/south panels extended towards EV side to increase the radiating area. These panels accommodate all payload elements including feeds and fixed reflectors. These panels together with top cylinder and shear webs can be assembled enabling the total integrated payload tests independently.

The bus module and payload module structure is given in Figure – 3.1. The exploded view of the bus module structure is given in Figure – 3.2.

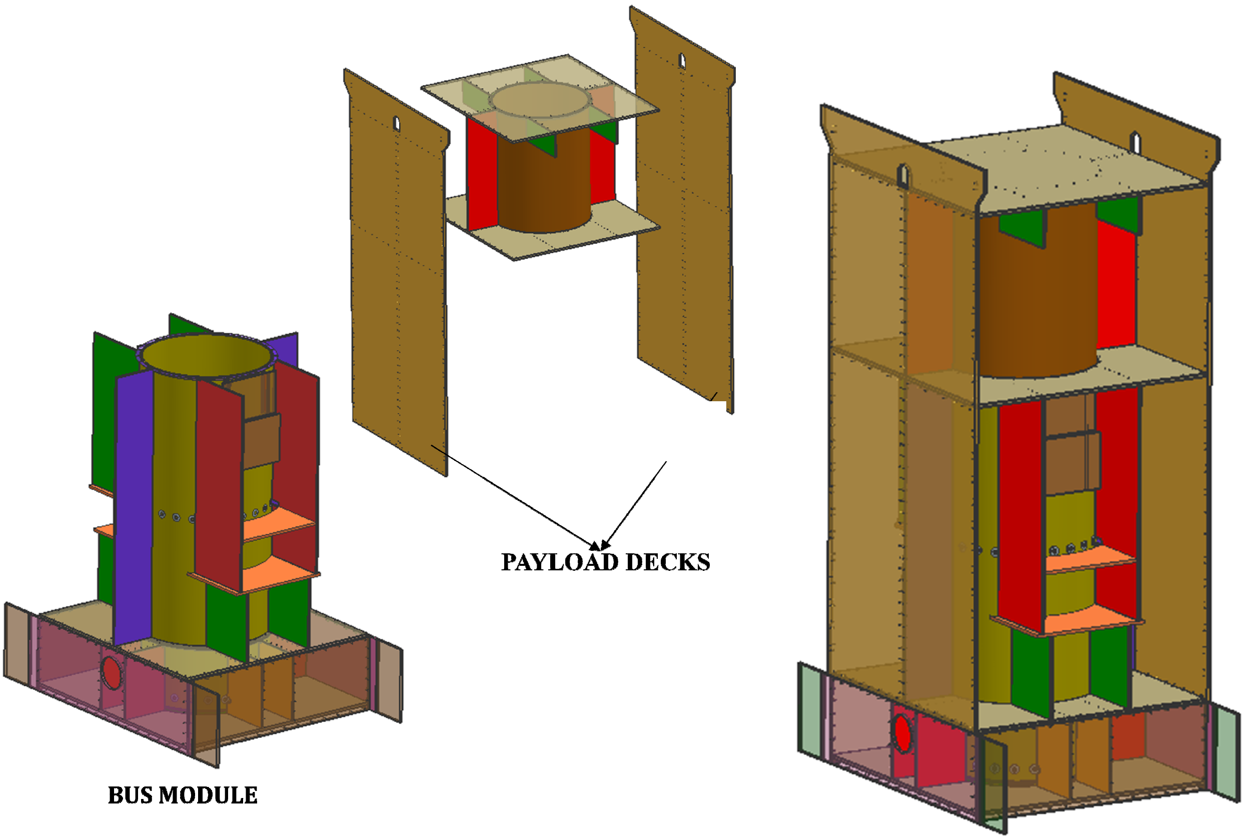


Figure 3.1: Bus module and the Payload module

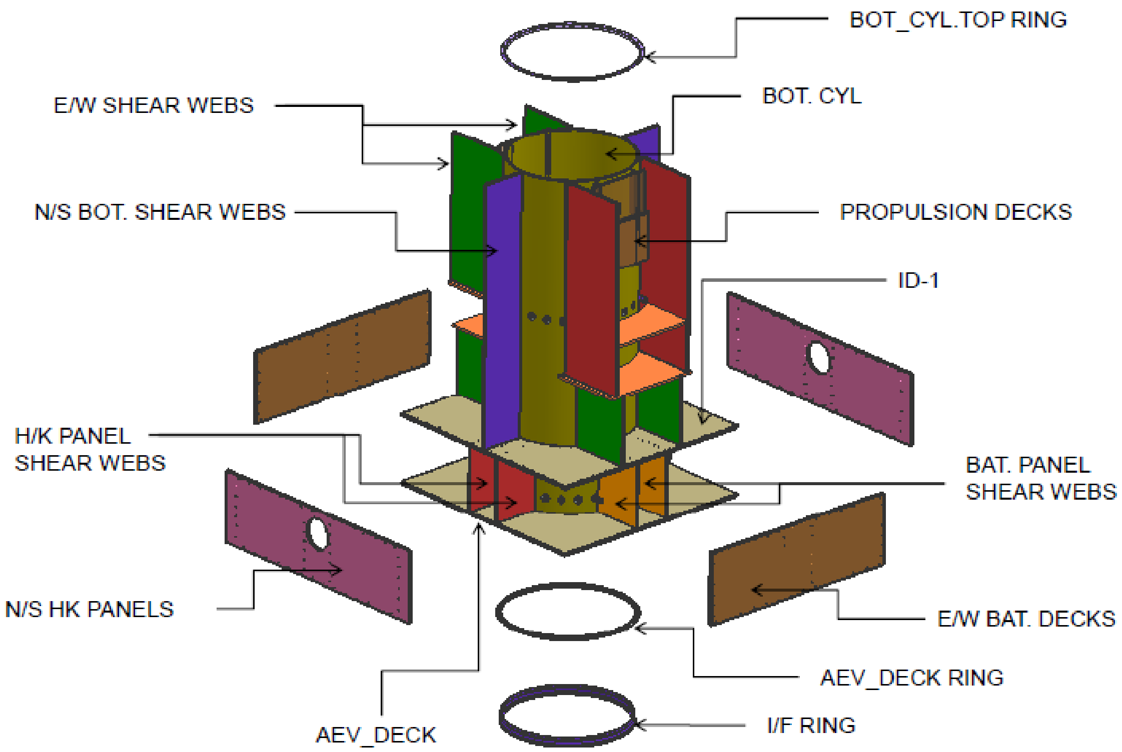


Figure 3.2: Exploded view of the Bus module

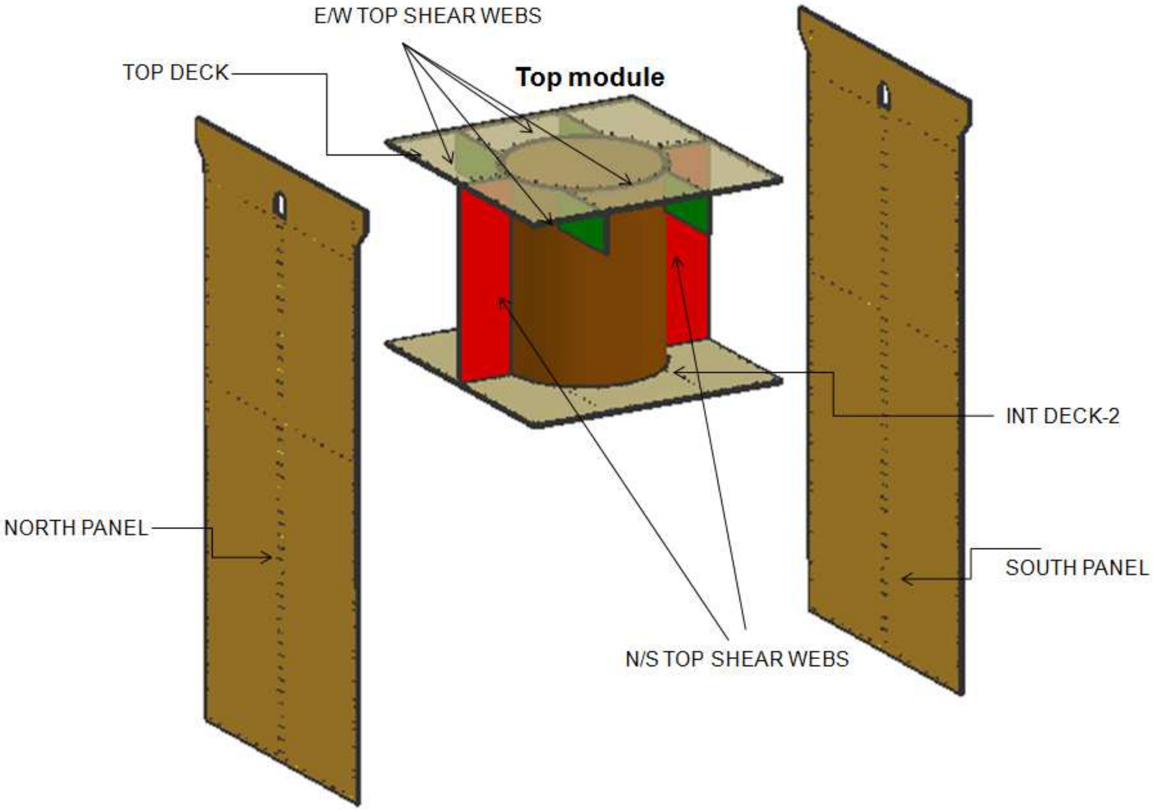


Figure 3.3: Exploded view of the Payload module

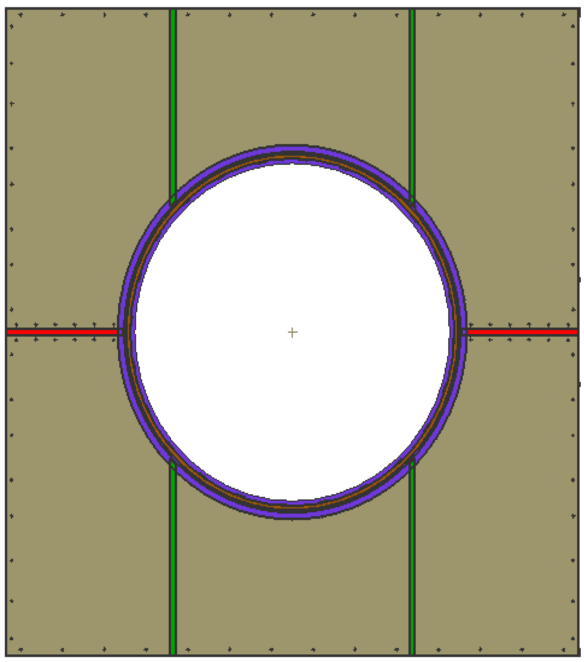


Figure 3.4: Plan of spacecraft structure (without vertical panels)

3.3 MAJOR SUBASSEMBLIES

3.3.1 Cylinder

- The thrust cylinder and shear webs are of honeycomb sandwich construction with CFRP face sheet and aluminium honeycomb core.
- The thrust cylinder accommodates cassini type propulsion tanks of 1450 lit. Capacity each.
- Each propellant tank is connected to the main cylinder at 24 discrete points
- At the connecting points on the cylinder there are post bonded split inserts
- The loads acting at the cylinder-tank interface are diffused to the cylinder by these inserts
- M10 bolts are used for attaching the tanks to the cylinder with a torque of 450 kgf-cm

3.3.2 Honey comb panels

- The east/west panels provide boundary conditions to north, south, and horizontal decks AEV, ID1, ID2 and EV.

3.3.3 Propulsion component module structure-CPS

- Propulsion component module structure can accommodate all propulsion components except fill& drain valves and thrusters
- The size of propulsion module are 700mm (w)x400 (h)mm ,which is attached to the cylinder on west side.
- This module allows independent integration of propulsion elements.

3.3.4 Momentum Wheel support structure

- Two Teldix momentum wheels are accommodated on the GSAT-11 structure with each wheel canted at 20 degrees.
- Wheels are mounted on two decks, called momentum wheel (MW) decks
- MW decks are located between two horizontal decks, called top MW deck and bottom MW deck
- The NE wheel is canted towards EV and SE wheel is canted towards AEV

3.3.5 LAM / pressurant tank support bracket:

- The LAM support structure supports the LAM engine (AR=250) with thermal heat shield.
- The LAM support structure consists of four CFRP sandwich radial ribs connected to the central titanium bracket. The central titanium bracket provide the interface for the LAM engine.
- The assembly is connected to the Interface ring/cylinder at four locations 900 apart through metallic brackets. The metallic brackets are bonded and riveted to the interface ring/cylinder region.
- CFRP sandwich ribs consists of CFRP face-sheets on either side of the 20mm thick aluminium honeycomb core.

3.3.6 Pressurant tank support structure:

- There are three pressurrant tanks, two located on West side and one on East side
- The tanks are connected to E/W intermediate shear panels through brackets
- Each tank has a volume of 67 lit and a mass of 15.2 kg
- At the fixed end a stiffener deck of size 400 mm X 270 mm (0.2 mm face sheet and 15 mm core) connecting the shear panel and East / West deck

3.3.7 Star sensor mounting bracket:

- There are two star sensors, which are mounted on N/S panel at the top deck intersection.
- Each Star sensors is mounted on Aluminium star sensor mounting bracket
- GFRP washers and external heat-pipes will be used for thermal control.

3.3.8 Deployable reflector supports:

- Four 2m deployable single shell Reflectors are accommodated 2 each on East / West side of cuboid. Suitable arrangement is made to support the hinge and hold down brackets on the structure. Reflector deployment and pointing mechanisms interface bracket support is provided by ID1 deck. Hold downs are supported on East/West shear webs and EV deck.

- There are total 12 numbers of Stand–off mounting structure which are to be mounted on the east and west panel to support the reflector. Two nos. of Stand-off hold down bracket required for South-East Antenna and Four nos. required for North-East Antenna. Similar two nos. for South-West and four nos. for North-West Antenna.

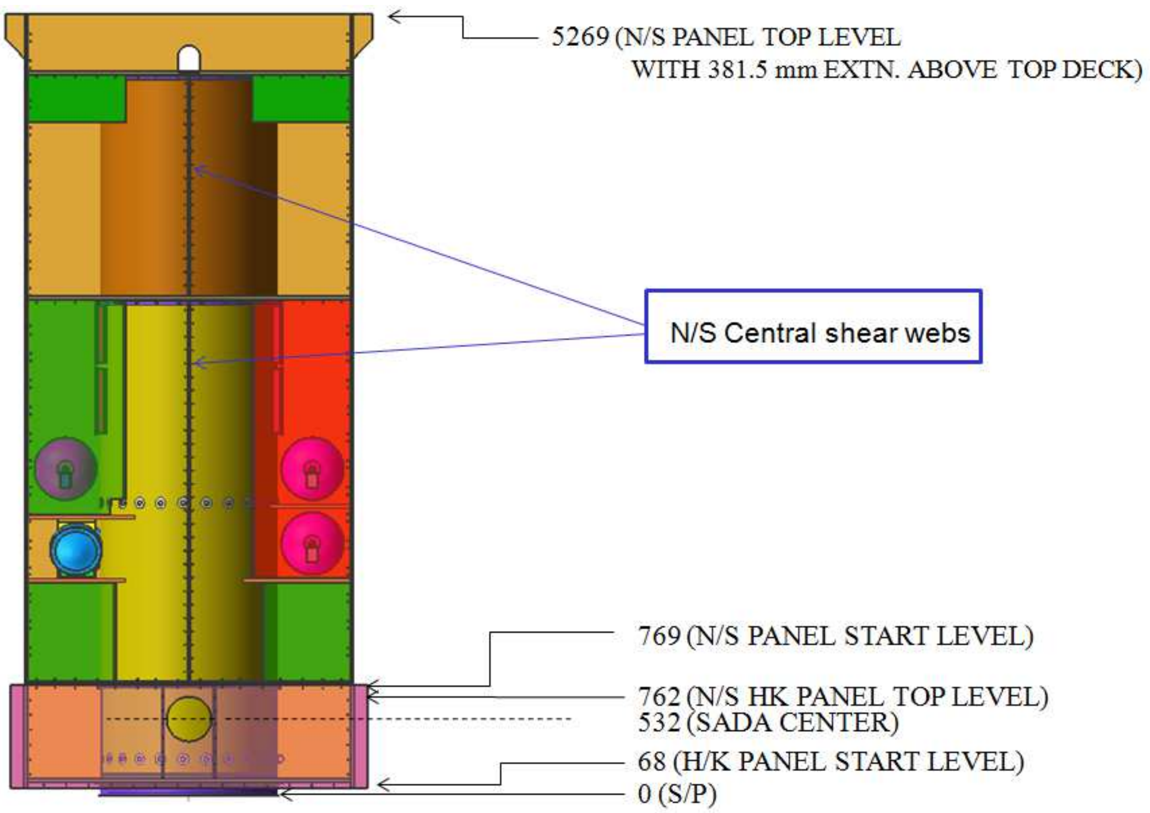


Figure-3.5 North/south view of structure

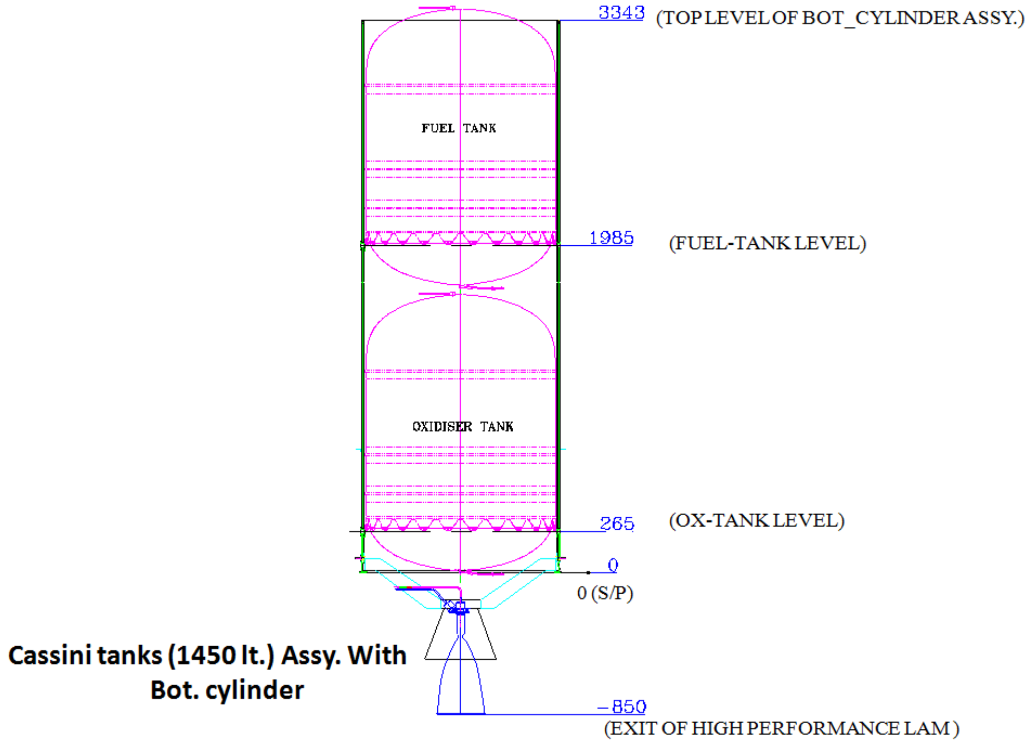


Figure-3.6 Cassini tanks Assy. With Bot cylinder

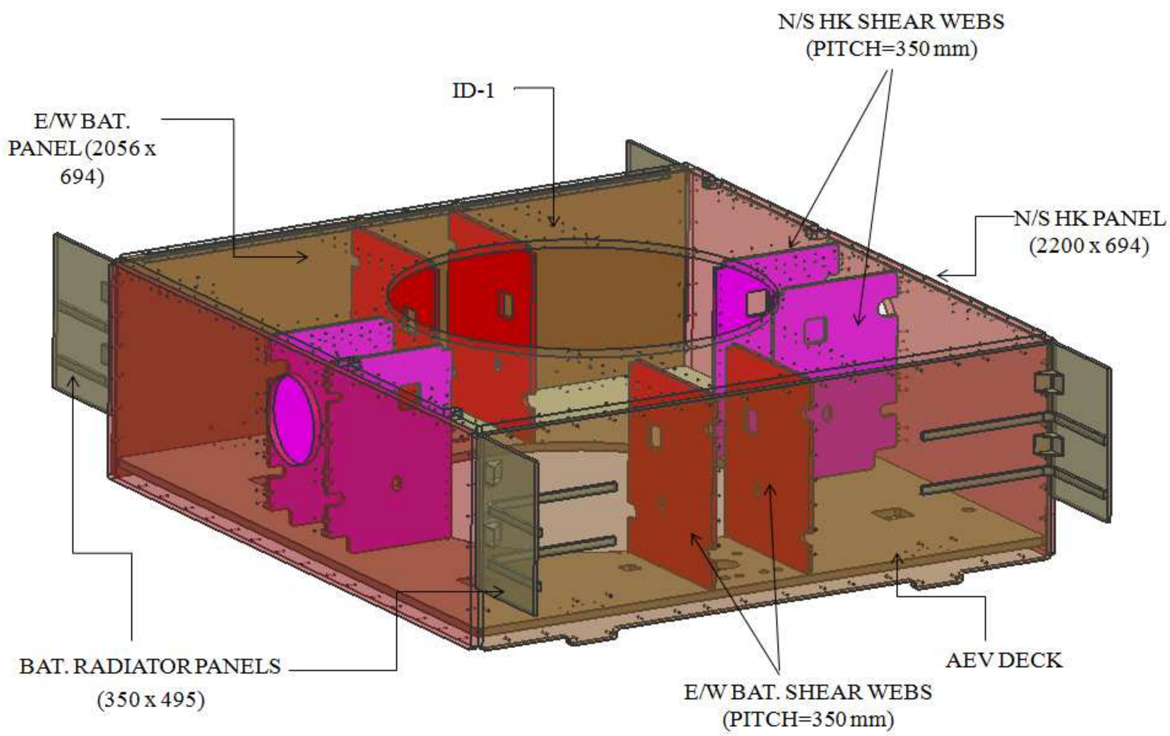


Figure-3.7 Battery radiator panels with Battery & HK panels

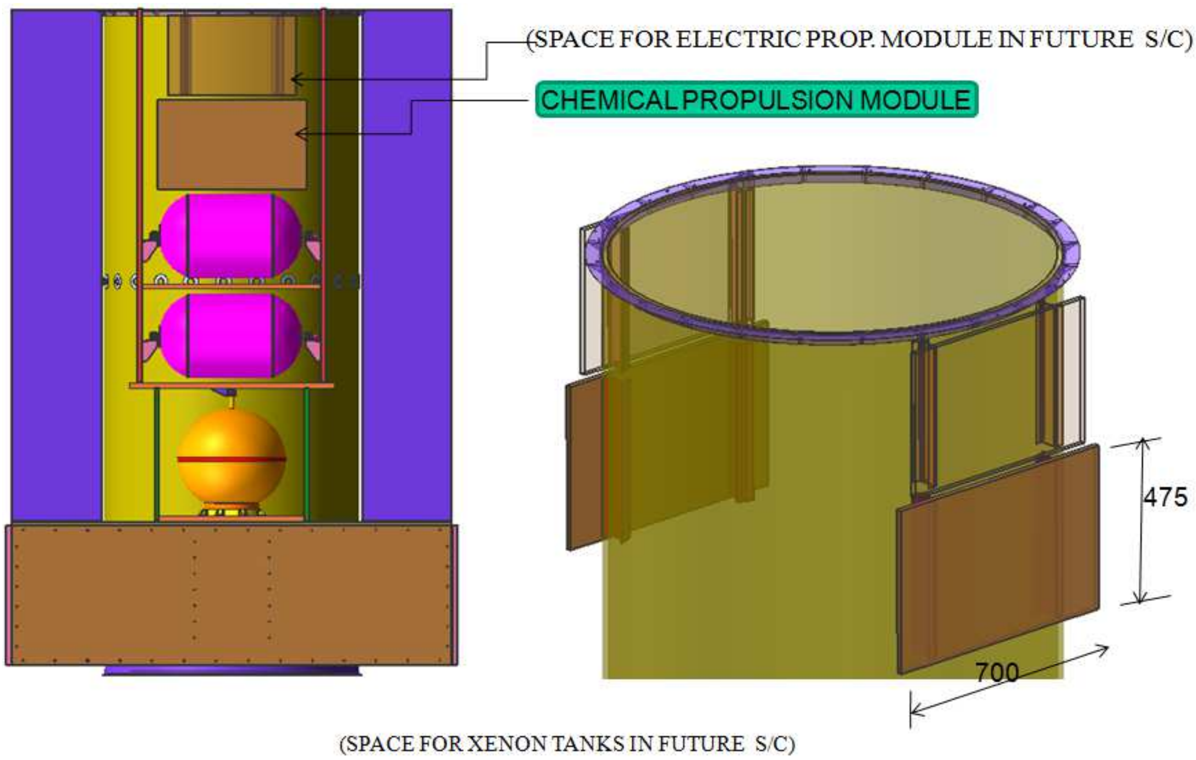


Figure-3.8 Propulsion Component Module

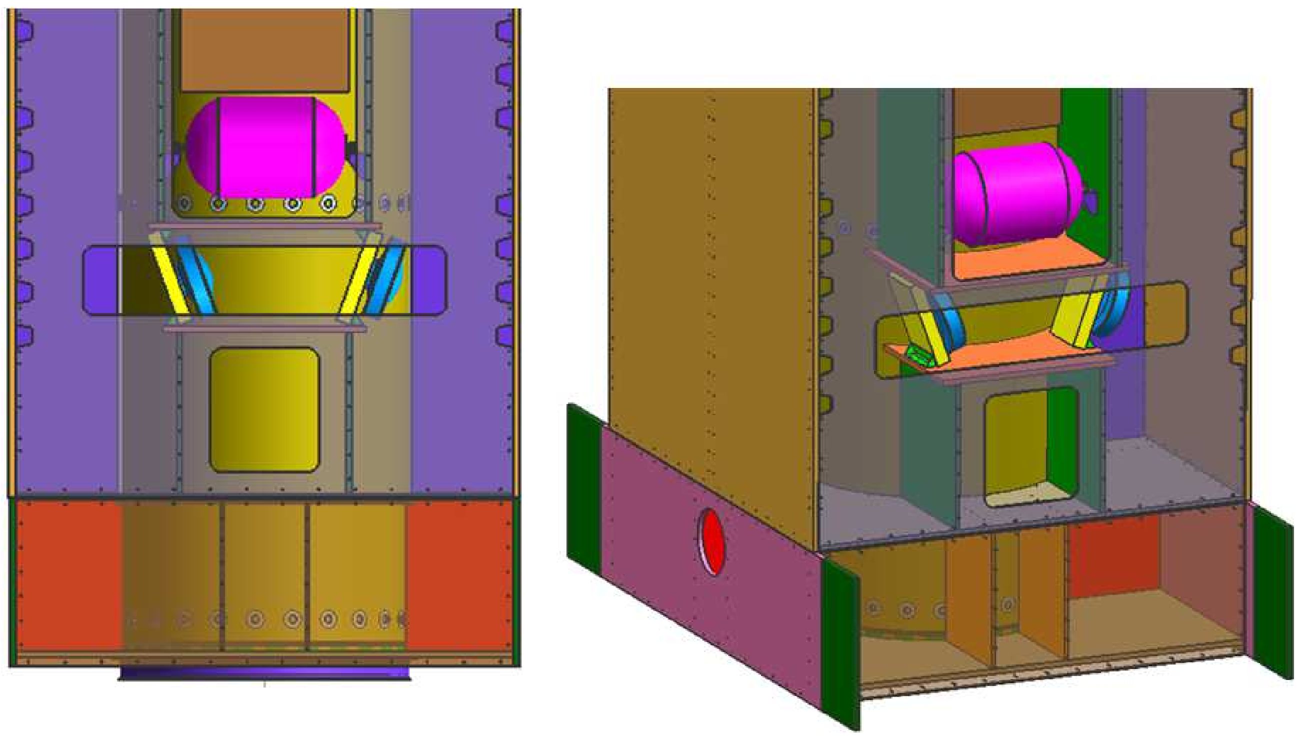


Figure-3.9 Assembly of momentum wheels & pr. Tank (east view)

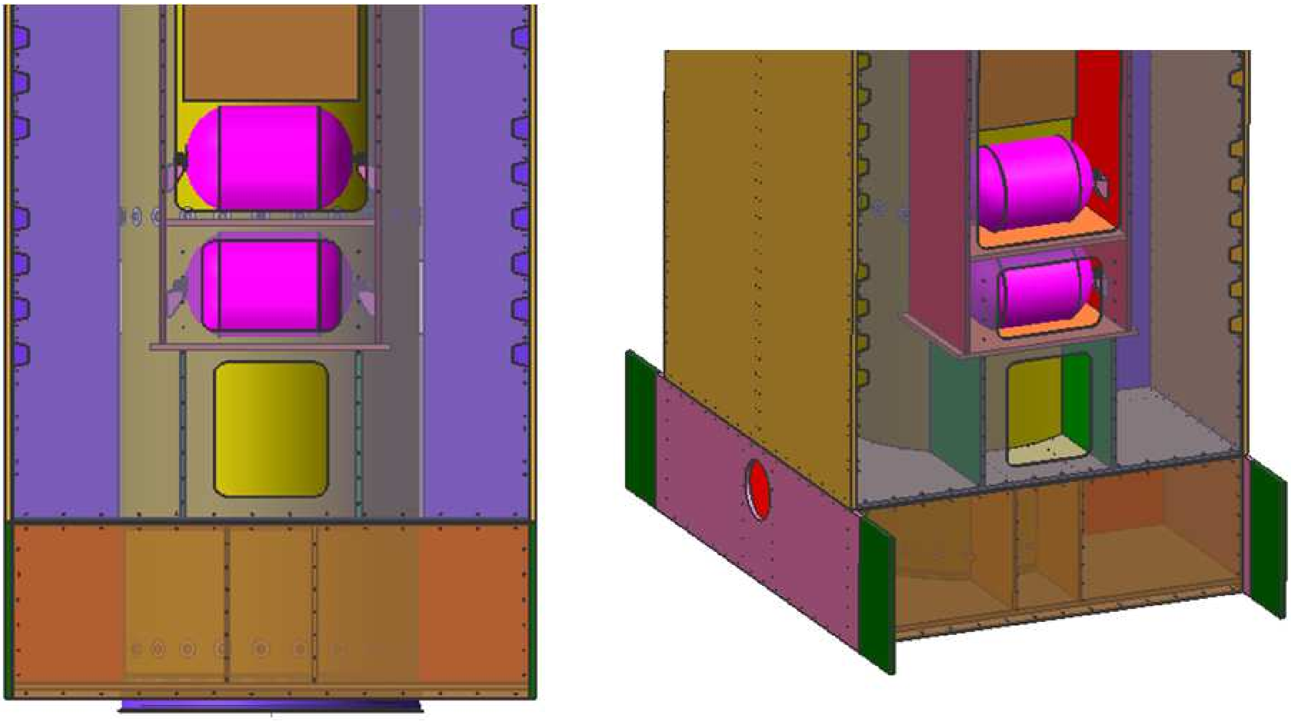


Figure-3.10 Assembly of pr. Tanks (west view)

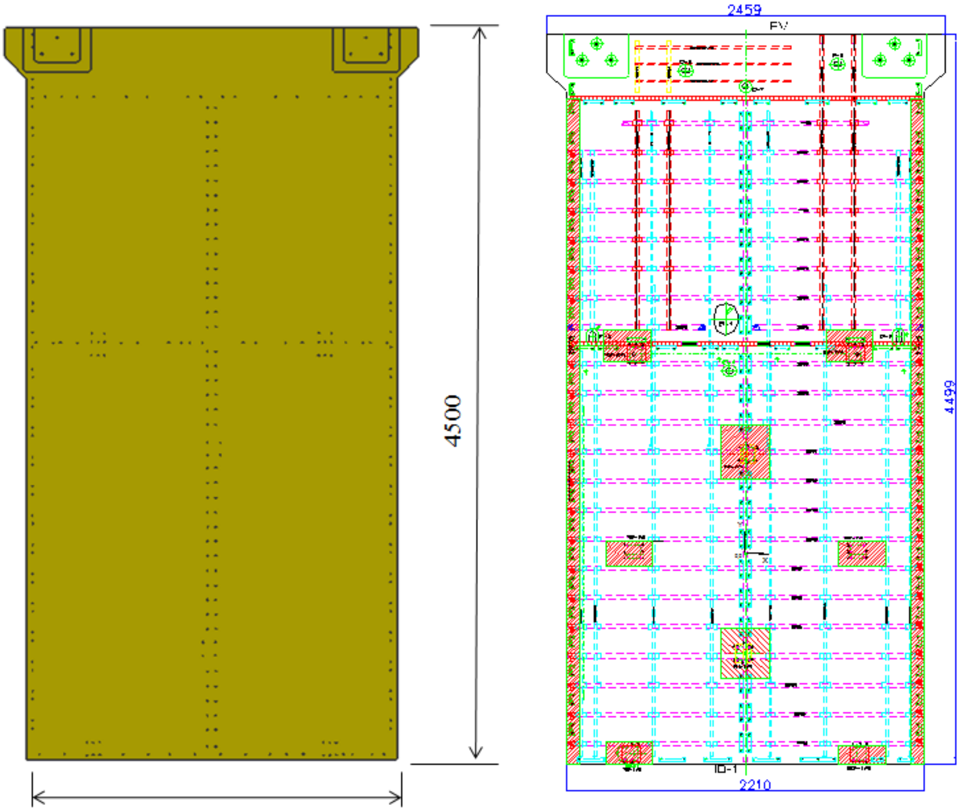
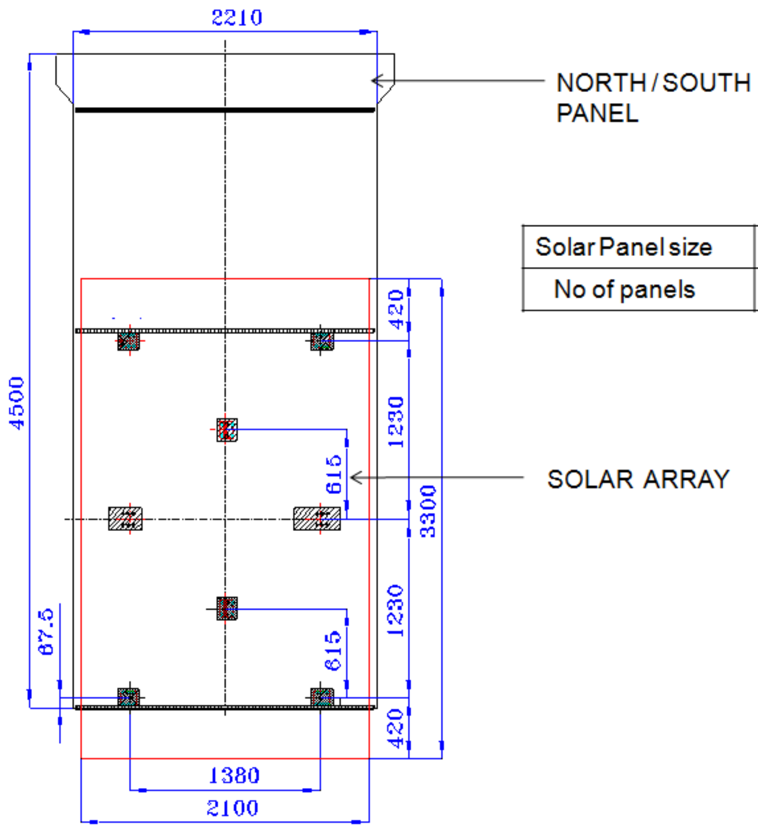


Figure-3.11 North/South (Equipment panels)



Solar Panel size	3300 x 2100
No of panels	5 + 5

Figure-3.12 Solar array interfaces

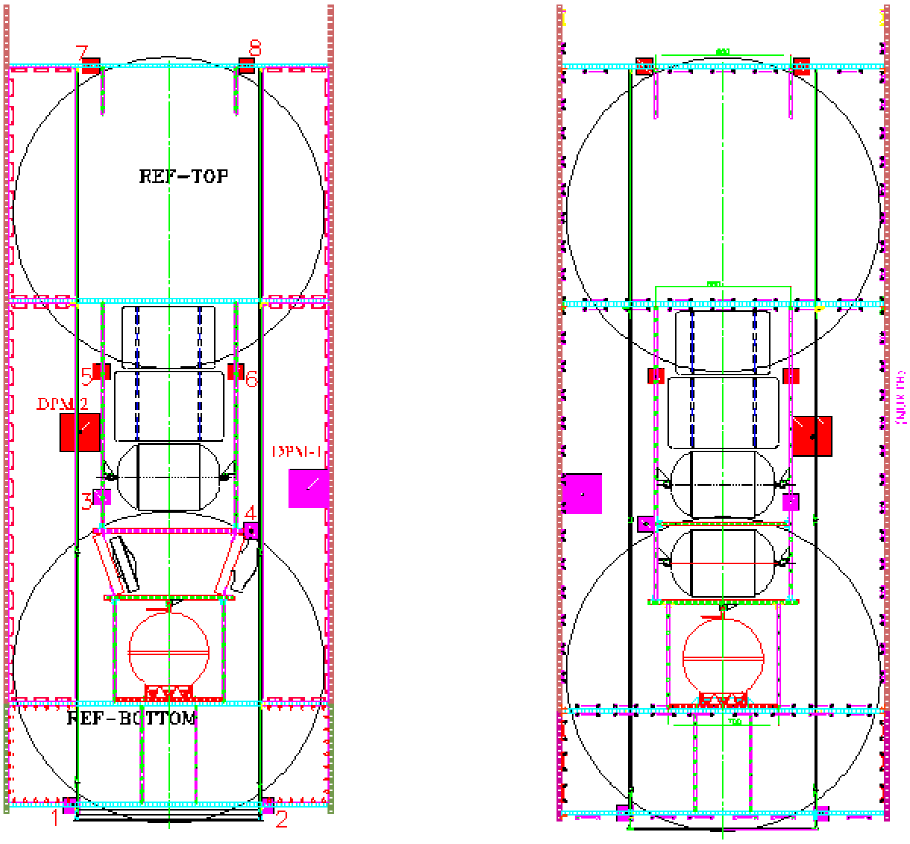


Figure-3.13 Reflector DPM and hold down interfaces

4 Thermal Systems

4.1 Introduction

GSAT-11 Spacecraft is advanced high power communication satellite providing multi beam services in Ku x ka band. The function of the thermal control system is to keep the temperature of the payload systems and mainframe subsystems housed in the spacecraft within the specified limits throughout the mission. The power requirement during Transfer Orbit and On Orbit phases is around 1.4 KW and 9.2KW respectively depending upon the power availability and operational requirements of the various subsystems of the satellite.

The panel wise thermal dissipation is as given below

North payload: 1640 W

South payload: 1342 W

ID-2: 294 W

EV: 232 W

NHK: 186 W

SHK: 170 W

ID-1: 311 W

The thermal control system comprises of both active elements like heat pipes, heaters and passive elements like multi-layer insulation (MLI) blankets, optical solar reflectors (OSR), thermal paints and coatings, etc as used in earlier missions

4.2 Thermal System Design

The thermal control system is designed to meet the temperature specification of various sub-system which are defined in the ETLC document for I-6K spacecraft No. ISRO-ISAC-GSAT-11-TE-2078 dated September 2014..

The thermal control of South, North and EV panels will be achieved using diffusers, embedded dual-core heat pipes and heaters. North and South panels are thermally interconnected using external & internal heat pipes through EV panel. The external face of North and South equipment panels are covered with optical solar reflectors. Heat pipe network for payload elements and main frame elements are independent to each other.

MLI blankets and heat shields are used for controlling the temperature of the spacecraft body and external elements.

Battery and the plumblines are covered with MLI blankets in order to radiatively de-couple from the rest of the body and to avoid freezing of the propellant in the plumblines.

The electronic packages (Payload and House-keeping) are mounted with grease as thermal filler. Whereas, sigraflex is used as thermal filler for surface mounted external heat pipes.

Thermal design of DGR typically consists of Germanium coated Kapton shield on front and MLI on rear side. Temperatures of the DGRs are monitored.

Heaters and temperature sensors are used for temperature management. Temperature will be monitored with thermistors (where the temperature range is small) and PRTs (where the temperature range is large). The heater power requirement is given in Table-4.1.

Total Number of Heaters	
Platform heaters	**176 (Includes both Main & Redundant)**
Payload Heaters	**83**
Thermistors	
Core thermisters	**204**
PIP thermisters	**200**
PRTs	
Mainframe	**57**
Payload	**23**

Table – 4.1: Heater Power Requirements

		In-Orbit		
Platform Heaters	**Transfer Orbit**	**Summer Solstice**	**Equinox**	
Subsystem/Location			**Sunlit**	**Eclipse**
Chemical Propulsion	135.0 W	100.0 W	97.0 W	97.0 W
Sensors	50.0 W	80.0 W	89.0 W	99.0 W
Wheels	0.0 W	0.0 W	0.0 W	0.0 W

Batteries	120.0 W	80.0 W	100.0 W	80.0 W
Housekeeping Panels	50.0 W	0.0 W	15.0 W	15.0 W
SADA	10.0 W	10.0 W	0.0 W	0.0 W
Spare	0.0 W	0.0 W	0.0 W	0.0 W
Platform Total	**365.0 W**	**270.0 W**	**301.0 W**	**291.0 W**

Payload Heaters	**Transfer Orbit**	**In-Orbit**		
		Summer Solstice	**Equinox**	
Subsystem/Location			**Sunlit**	**Eclipse**
Payload Compensation Heaters	400.0 W	0.0 W	0.0 W	0.0 W
Reflector Deployment and Pointing Mechanisms	40.0 W	40.0 W	40.0 W	80.0 W
Feeds	50.0 W	30.0 W	30.0 W	30.0 W
EV TTC Rx/Tx Zone	50.0 W	0.0 W	0.0 W	0.0 W
Payload Total	**540.0 W**	**70.0 W**	**70.0 W**	**110.0 W**

Total Heater Power Requirement	**905.0 W**	**340.0 W**	**371.0 W**	**401.0 W**

5 Deployment Mechanisms

5.1 Introduction

GSAT-11 spacecraft will have following mechanisms:

1. Solar Array Deployment Mechanism - Two wings of 5 panels each with ‘T’ shape array on North and South sides.
2. Reflector Deployment and Pointing Mechanism – Four no. of 2 m indigenously fabricated single shell parabolic reflector (each independently held and steerable about pitch and Roll axes) with two reflectors mounted on east and west sides

These appendages are stowed during launch and are deployed in-orbit.

5.2 Solar Array Deployment Mechanism (SADM)

The solar array consists of two wings of 5 panels, each of size 3300 x 2100 mm mounted on North and South sides of spacecraft. The array is connected to the spacecraft through a yoke and a Solar Array Drive Assembly (SADA). The yoke houses the mating connectors for mating the solar panel and SADA harness. The solar panels along with yoke are stowed on the north and south panels and held by means of eight hold down bolts that resists the launch loads. The panels are folded such that the cell side of panel-3 is exposed to outside in stacked condition so that the outermost panel generates power in Transfer Orbit (T.O).

On cutting of the rope by a centrally placed pyrotechnic cutter, all the levers will be relieved from the wire rope load and are pulled away to release the plungers holding the hold down bolts. One cable cutter is used for deployment of each solar array wing. After the main panel depoyment is completed, the side panel deployment is initiated. The side panels deploy on either sides of the 1st panel. The stowed and deployed array is shown in figure-5.1 & figure 5.2. The design specifications are given in Table 5.1.

Table 5.1 Design specifications

Sl No	Details	Specifications
1.	No. of panels	5 panels/wing
2.	Panel size	3300 x 2100 x 20 mm
3.	Clearance between spacecraft North/South deck and first solar panel	143 mm
4.	Inter panel gap - Cell side - Back side	 20.0 mm 19.0 mm
5.	Total stack height (from spacecraft deck to outermost panel)	325.25 mm
6.	Length of yoke (bearing to bearing)	3056.8 mm
7.	Deployed length from S/c deck	13324 mm
8.	No. of hold down points	8
9.	Hold Down bolt preload at each point	900 Kgf & 1100 kgf
10.	Tension in the primary hold down loop near Pyrocutter	224 Kgf (max)
11.	Latch up moment load -at inter panel hinge -at yoke SADA hinge -at Side panel Hinge	 205 Nm max. & SF=205 N 465 Nm max. & SF=154 N 95 Nm max & SF=50 N
12.	Nominal tension in CCL loop-SS 301 Kevlar	8 Kgf 3 Kgf
13.	Stowed stack frequency	~ 40 Hz
14.	Deployed array natural frequency	~ 0.05 Hz
15.	Design load (in stowed position)	30 g out of plane 20 g in plane
16.	Panel centre line to centre line spacing at hinge Interfaces	40 mm
17	Temperature specifications Before deployment - Hold down and release assembly - Inter panel hinge assembly	 - 100 to + 100 deg. C - 105 to + 85 deg. C
	During Deployment - Inter-panel Hinge & Damper Assembly After Deployment	 0 to + 70 deg. C - 145 to + 100 deg. C

Figure-5.1 Solar Array in deployed configuration

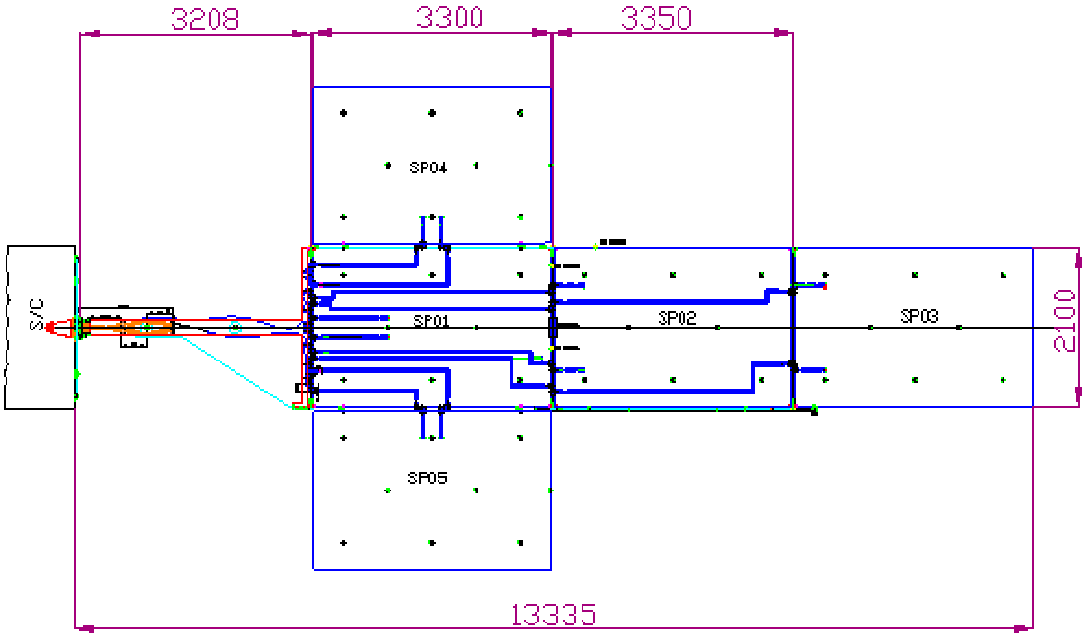


Figure-5.1 Solar Array in deployed configuration

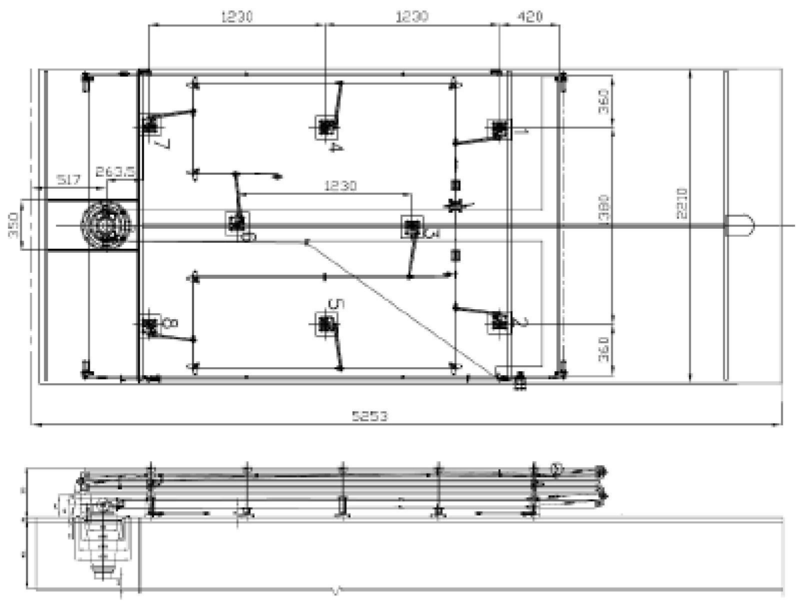


Figure-5.2 Solar Array in stowed configuration

5.3 Reflector Deployment Mechanism

GSAT-11 payload configuration is proposed with four Ku band reflectors of 2 m diameters mounted on east and west faces (2 on each side) of the spacecraft as shown in figure-5.3. Each reflector will have four beams of which one of the beams will be used for closed loop tracking. The reflectors will have on-board RF tracking for accurate antenna pointing. These reflectors are stowed on east and west faces of the spacecraft during launch and deployed and steered on-orbit for pointing.

Each Reflector mechanism consists of hold down and release mechanism (HDRM) and a two axis deployment and Pointing mechanism (DPM). The HDRM holds the reflectors during launch phase and in orbit till the reflectors are deployed. The reflector is deployed and steered on-board with two axes DPM as shown in figure-5.4. DPM is used to correct the antenna pointing continuously in closed loop within a RF range of ± 0.4º.

Reflector specifications:

- Size of the main reflector : 2m
- Focal length : 2.6m
- Mass of the main reflector : 16.5Kg
- Alignment specification for each reflector:
- Pitch and Roll orientation : ± 0.02°
- Yaw : ± 0.1o
- Vertex location : ±1.0 mm

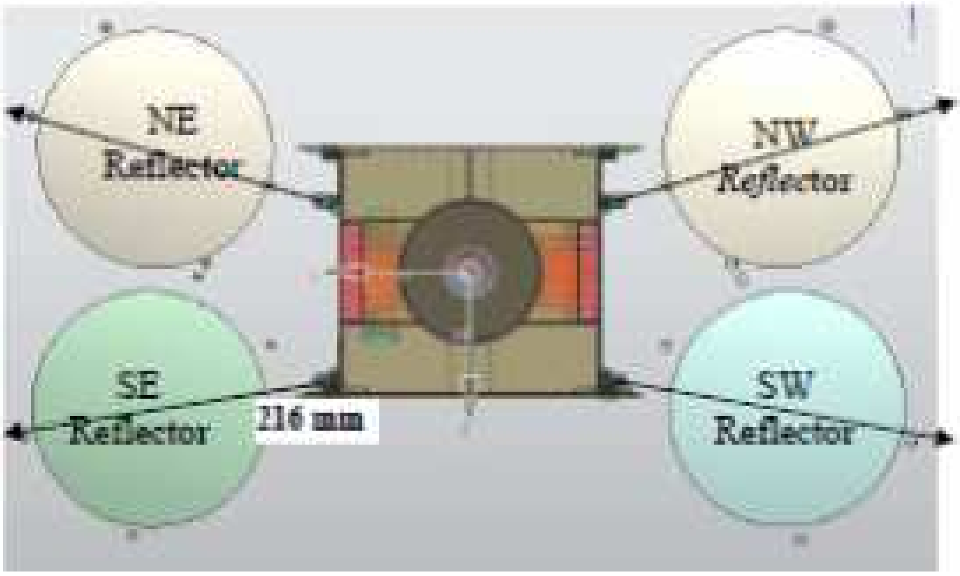


Figure-5.3 Reflector in deployed configuration

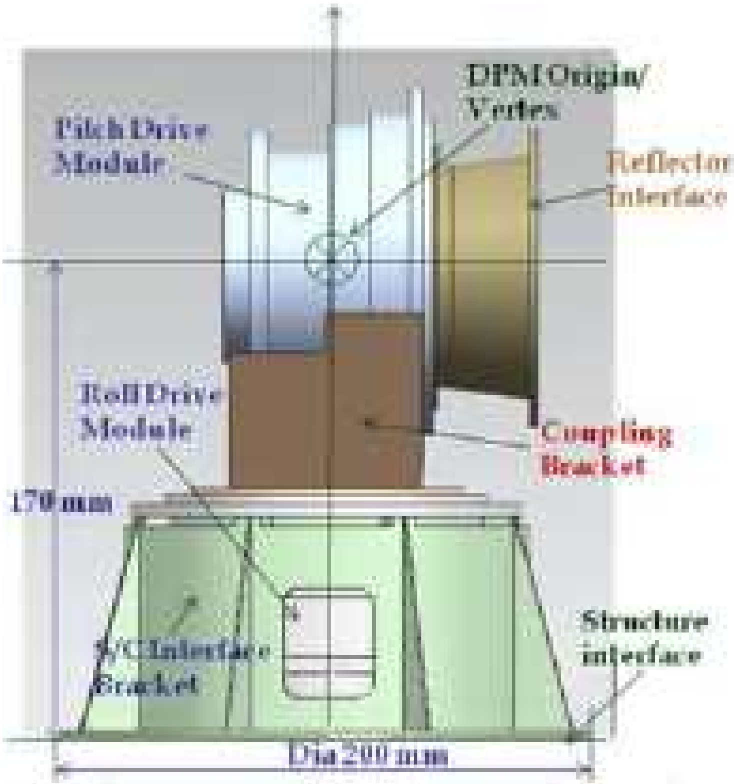


Figure-5.4 Deployment and Pointing Mechanism (DPM)

6 Spacecraft Propulsion System

6.1 Introduction

Propulsion system in GSAT-11 Spacecraft is required during different phases of the spacecraft mission such as:

- ✓ Transfer orbit attitude correction
- ✓ Orbit raising to synchronous orbit
- ✓ Station acquisition
- ✓ Station keeping
- ✓ Momentum dumping.
- ✓ Contingency operations etc.

The spacecraft lift of mass and propellant mass is detailed below

The spacecraft lift of mass	=	5775 kg
Mass of Propellants	=	3194 kg (95 % filling)
Propellant Tank volume	=	2 no. of 1450 litre
Helium Tank Volume	=	3 No. of 67 llitre
Maximum Helium Pressure	=	250 bar
Spacecraft on-orbit life	=	15 years
Operating voltage of Components	=	70 Volts

6.2 Propulsion Systems Configuration

The propulsion system of GSAT-11 is configured with Unified bi-propellant chemical propulsion system employing Nitrogen Tetroxide (N_2O_4) as Oxidiser and Mono Methyl Hydrazine (MMH) as fuel. The propulsion system is broadly classified as two modules:

- ✓ Pressurant Module
- ✓ Propellant Module

The propulsion System Schematic is shown in Figure – 6.1.

6.2.1 Pressurant Module

The propulsion system consists of a pressurant module which employs:

- ✓ 3 Pressurant tanks of 67 L
- ✓ Fill and drain valves
- ✓ Pyro valves which are normally closed for high pressure isolation
- ✓ Pressure transducer to indicate the pressure
- ✓ Test ports for servicing
- ✓ Pressure regulators regulating the pressure required
- ✓ Check valves in series
- ✓ One Bi-propellant latch valve (LVG) and two Single flow latch valves (one each in oxidiser and fuel line) parallel to LVG

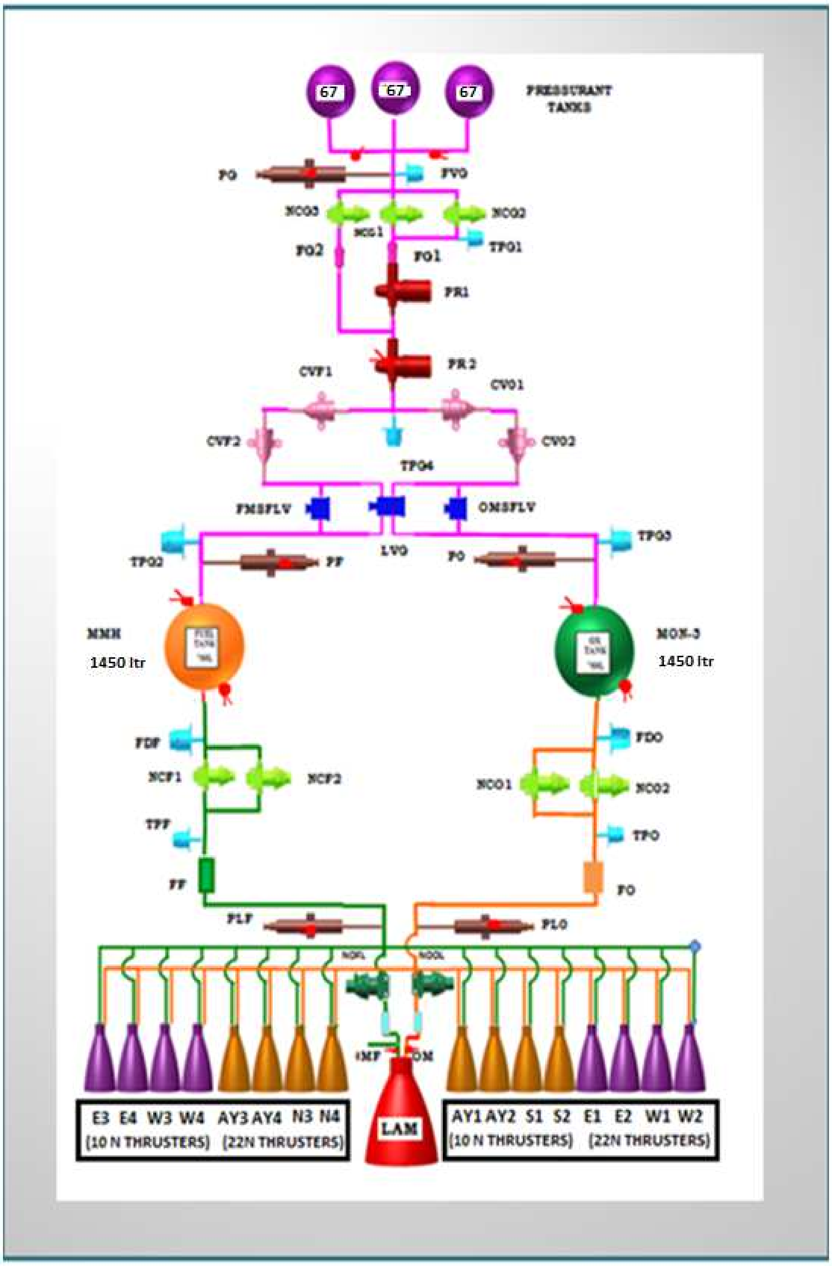
6.2.2 Propellant Module

GSAT-11 propellant module employs:

- ✓ Propellant tanks of 1450 L capacity.
- ✓ Fill and drain valves
- ✓ Test ports for servicing
- ✓ Pressure transducers to indicate pressure both on liquid and gas sides
- ✓ Pyro valves with redundancy
- ✓ One filter each for fuel and oxidizer
- ✓ Liquid apogee motor connected through normally open pyro valves
- ✓ 10 N and 22 N thrusters valves opearted at 70 V – Eight numbers each

The propulsion System Schematic is shown in Figure – 6.1.

Figure – 6.1: Propulsion System Block Schematic



6.2.3 PROPULSION SYSTEM SPECIFICATIONS

1	**Type**	Active, Bipropellant (MON-3, MMH) system
2	**System operating pressure**	Regulated mode for Apogee maneuvers at a tank

		pressure of 16.5 bars (Nominal). Blow down mode for AOCS thrusters from 16.5 bar at BOL to 11.5 bar at EOL
3	**Thruster rating**	440 N X 1 Engine (250 AR) 22 N X 8 Thrusters 10 N X 8 Thrusters
4	**MEOP of Pressurant Tank**	250 bar of GHe (3 No 67 ltr tank)
5	**MEOP of Propellant Tank**	17.5 bar
6	**LAM inlet pressure**	14.3 bar (nominal) with PR1 15.3 bar (nominal) with PR2
7.	**AOCS inlet pressure**	16.5 bar at BOL and 11.5 bar at EOL
8.	**Propellant Mass with 1450 liter tanks (95 % filling) at 20° C**	3194 MMH : 1205 kg MON-3 : 1989 kg MR : 1.65 (TBD)

7 Composites

7.1 Introduction

Apart from spacecraft structure elements, following elements of GSAT-1 are made of composite elements:

Table – 7.1: List of Composites Deliverables

2 m single shell ku band deployable reflector	: 4 nos.
1.4m ka band fixed antenna	: 1 no.
Solar panel substrate	: 10 nos.
Solar Array yoke	: 2 nos.
SADA cones	: 2 nos.
Pressurant tanks (67 litre)	: 3 nos.

The section below provides the specifications for Ka band and Ku band antennae. Other composite elements are standard productionized elements and specifications are same as earlier spacecrafts.

7.1.1 Ka-Band Antenna Specification

Single offset parabolic reflector antenna with 1.4 meter diameter and focal length of 1.4 meter is designed to meet the EOC gain requirement and feed cluster can be placed and accommodated on the EV top. This antenna will be mounted on EV top. Feeds will be mounted on the mast.

SL No	PARAMETER	SPECIFICATION
1.	Configuration & type	Offset fed, fixed
2.	Reflector mounting location	EV Deck
3.	Aperture Diameter of reflector	1400 mm+/- 3mm
4.	Focal length	1400 mm
5.	Reflector offset	300 mm
6.	Shape	Parabola

SL No	PARAMETER	SPECIFICATION
7.	Operating frequency	Ka-band (Tx- 19.7-20.2 GHz Rx- 29.5 – 30.0 GHz) For info only
8.	RMS error of reflector surface (as manufactured)	< 0.15 mm
9.	RMS error due to Thermal Distortion, Hygroscopic effects etc.	< 0.20 mm
10.	Surface Profile Deviation Peak to Valley	<0.9mm < 0.75 mm (Goal)
11.	R.M.S Error of mould	< 50 micron
12.	Antenna Mechanical Tilt	Antenna Reflector Dish & feed Interfaces to have 3.58^0 northward tilt about the reflector vertex.
13.	Weight of whole antenna assembly with out feed & Wave guide	< 26 Kg <24 Kg (Goal)
14.	Reflector Material	Cu clad kapton on CFRP. Al clad Kapton is also acceptable.
15.	Feed mast material	CFRP
16.	Reflector and Mast integrity requirement	Feed mast to be integral part of reflector structure.

7.1.2 Ku band South East Reflector Specification:

SL No	PARAMETER	SPECIFICATION
1.	Configuration & type	Offset fed, Deployable
2.	Reflector mounting location	Deployable on East Deck, after deployment it will be in South East corner of spacecraft
3.	Reflector Stowing Configuration	Stowed with Reflecting side towards deck.
4.	Reflector shell Material	CFRP
5.	Mass	16.5 Kg
6.	Projected Aperture Diameter of reflector	2000 mm ± 3mm
7.	Focal length	2900 mm

8.	Reflector offset	450 mm
9.	Reflector Rotation about Yaw Axis in Deployed condition	**11°** about spacecraft Yaw axis in **counter clock wise** rotation while looking towards reflecting side of reflector
10.	Shape	Parabola
11.	Operating frequency	Ku-band Transmit and Receive (for info only)
12.	Manufacturing RMS Error of reflector surface	< 0.20 mm
13.	Surface Profile Deviation Peak to Valley	< 0.75 mm
14.	RMS error of mould	< 60 micron (will be provided by SAC)
15.	RMS error of the reflector due to Thermal Distortion, Hygroscopic effects etc.	< 0.20 mm
16.	Antenna Mechanical Tilt in deployed configuration	0.05° towards West(pitch) and 3.0° towards North (Roll). The westward tilt is achieved by reflector DPM mechanism. & Northward tilt is achieved by DPM interface with reflector

7.1.3 Ku band South West Reflector Specification:

SL No	PARAMETER	SPECIFICATION
17.	Configuration & type	Offset fed, Deployable
18.	Reflector mounting location	Deployable on west Deck, after deployment it will be in South west corner of spacecraft
19.	Reflector Stowing Configuration	Stowed with Reflecting side towards deck.
20.	Reflector shell Material	CFRP
21.	Mass	16.5 Kg
22.	Projected Aperture Diameter of reflector	2000 mm ± 3mm
23.	Focal length	2900 mm
24.	Reflector offset	450 mm
25.	Reflector Rotation about Yaw Axis in Deployed condition	**11°** about spacecraft Yaw axis in **clock wise** rotation while looking towards reflecting side of reflector
26.	Shape	Parabola
27.	Operating frequency	Ku-band Transmit and Receive (for info only)
28.	Manufacturing RMS Error of reflector surface	< 0.20 mm

29.	Surface Profile Deviation Peak to Valley	< 0.75 mm
30.	RMS error of mould	< 60 micron (will be provided by SAC)
31.	RMS error of the reflector due to Thermal Distortion, Hygroscopic effects etc.	< 0.20 mm
32.	Antenna Mechanical Tilt in deployed configuration	0.05° towards West(pitch) and 3.62° towards North (Roll). The westward tilt is achieved by reflector DPM mechanism. Northward tilt is achieved by DPM interface with reflector

7.1.4 Ku band South North East Reflector Specification:

SL No	PARAMETER	SPECIFICATION
1.	Configuration & type	Offset fed, Deployable
2.	Reflector mounting location	Deployable on East Panel, after deployment it will be in North East corner of spacecraft.
3.	Reflector Stowing Configuration	Stowed with Reflecting side towards deck.
4.	Reflector shell Material	CFRP
5.	Mass	16.5 Kg
6.	Projected Aperture Diameter of reflector	2000 mm ± 3mm
7.	Focal length	2600 mm
8.	Reflector offset	450 mm
9.	Reflector Rotation about Yaw Axis in Deployed condition	**18°** about spacecraft Yaw axis in **clock wise** rotation while looking towards reflecting side of reflector
10.	Shape	Parabola
11.	Operating frequency	Ku-band Transmit and Receive (for info only)
12.	Manufacturing RMS Error of reflector surface	< 0.20 mm
13.	Surface Profile Deviation Peak to Valley	< 0.75 mm
14.	RMS error of mould	< 60 micron (will be provided by SAC)
15.	RMS error of the reflector due to Thermal Distortion, Hygroscopic effects etc.	< 0.20 mm
16.	Antenna Mechanical Tilt in deployed configuration	0.27 deg towards East and 4.450 towards North.

7.1.5 Ku band North West Reflector Specification:

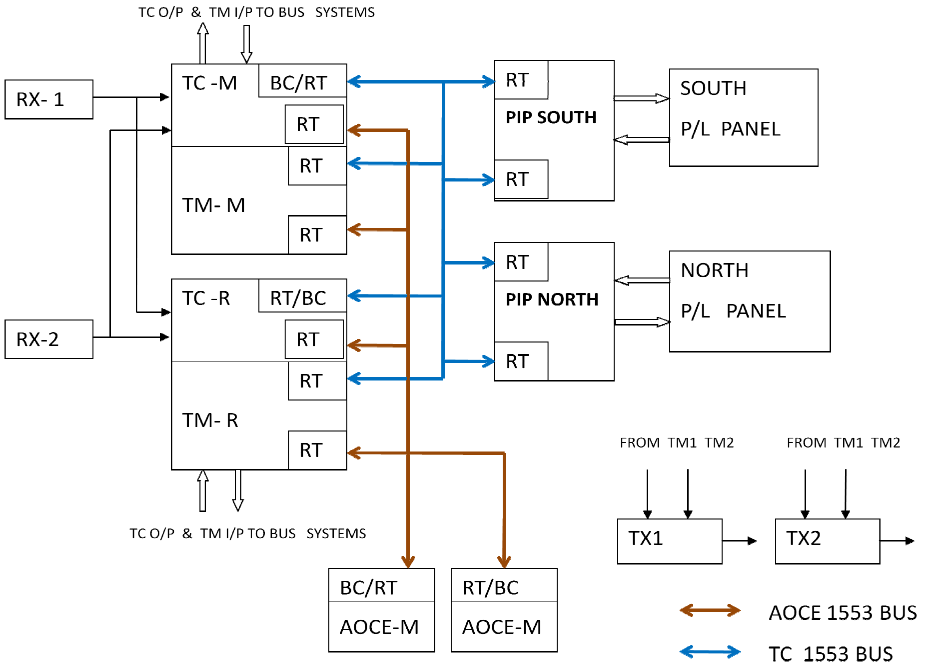
SL No	PARAMETER	SPECIFICATION
17.	Configuration & type	Offset fed, Deployable
18.	Reflector mounting location	Deployable on West Panel, after deployment it will be in North West corner of spacecraft.
19.	Reflector Stowing Configuration	Stowed with Reflecting side towards deck.
20.	Reflector shell Material	CFRP
21.	Mass	16.5 Kg
22.	Projected Aperture Diameter of reflector	2000 mm ± 3mm
23.	Focal length	2600 mm
24.	Reflector offset	450 mm
25.	Reflector Rotation about Yaw Axis in Deployed condition	**18°** about spacecraft Yaw axis in **counter clock wise** rotation while looking towards reflecting side of reflector
26.	Shape	Parabola
27.	Operating frequency	Ku-band Transmit and Receive (for info only)
28.	Manufacturing RMS Error of reflector surface	< 0.20 mm
29.	Surface Profile Deviation Peak to Valley	< 0.75 mm
30.	RMS error of mould	< 60 micron (will be provided by SAC)
31.	RMS error of the reflector due to Thermal Distortion, Hygroscopic effects etc.	< 0.20 mm
32.	Antenna Mechanical Tilt in deployed configuration	0.18° towards West & 2.26° towards North

8 TTC-BB

8.1 Introduction

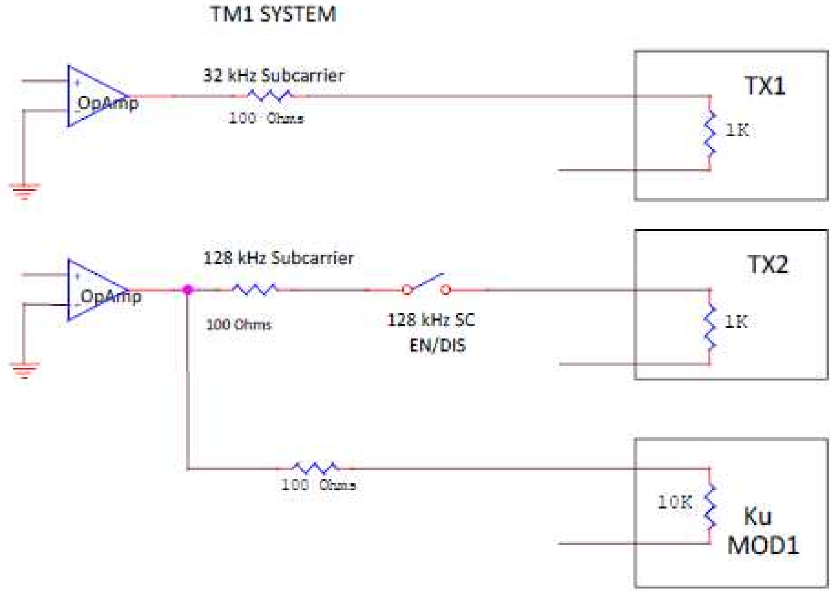
GSAT-11 TT&C Base band system has been designed to cater to TM & TC requirements of I4K bus and I6K bus. The system has been realized with two core packages & two PIP packages. Core packages are standardized to provide TMTC requirements of I4K & I6K main frame systems. Similarly PIP packages provide the TMTC requirements of I4K/I6K Payload systems & these packages can be tailored to meet the Payload requirements.

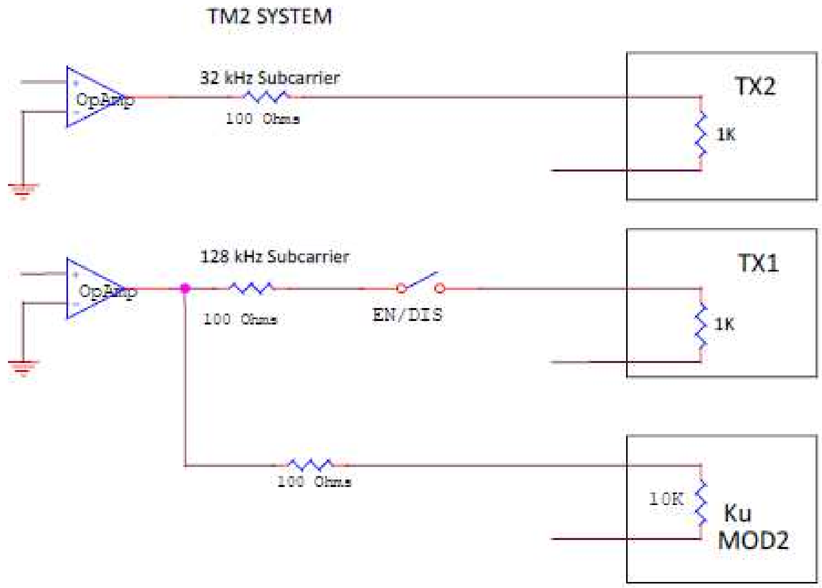
The Telecommand system is hot redundant system which decodes the uplinked (transmitted) command & provides the command information and data in binary form for the operation of various subsystems onboard the spacecraft during various phases of the mission. GSAT-11 Telecommand system is CCSDS command system with a provision for command encryption and authentication. The system has the data/command uplink capability from few bytes up to 1Kilo byte to the systems onboard during one transfer frame. To cater to this throughput requirement 500bps CCSDS type Telecommand format with PSK modulation is chosen. Telecommand system decodes the command & provides command pulses with different amplitudes & pulse widths with isolated command interfaces. The Telecommand system operates in C-band and the PSK Demodulator is housed inside TTC-receiver package. Digital signals from receiver package are fed to the decoders. PSK demodulator provides digital data, clock and lock (5V TTL level) signals to TMTC package. Cross strapping exists between the command decoder and the Receiver as shown in the figure-8.1. The Telecommand system also provides features of Thermal management, Stored command execution with events, Time tag delays & OBT. The system has autonomy features of Telecommand processor (TCP) change over, TM change over & 1553 bus change over etc.



The Telemetry system is CCSDS TM system which accepts data from various other subsystems within the spacecraft in either Analog or Digital form. The core telemetry system along with Payload Interface Telemetry controls all the functions for the generation of Telemetry data. The final serial data in PCM format is modulated on PSK sub-carrier, which are having appropriate band pass filter at its output to avoid interference with the Ranging tones. The Telemetry system supports Normal & programmable & Dwell formats (up to 16 parameters). Telemetry core system is configured as two identical hot redundant systems. The Telemetry formatter is based on the stored program format provided in the PROM.

The normal and dwell data at 32 KHz and 128 KHz subcarriers from the TM encoder package is given to transmitters TX-1, Tx-2 and the Ku beacon modulator as shown in the figure 8.2. Transformer coupled interface exists between the TM modulator and the Transmitter/Ku beacon modulator for galvanic isolation.





8.1.1 Salient Features of Telecommand System

- CCSDS TC & TM System
- PSK subcarrier modulation
- The system incorporates CCSDS command decoder with encryption and authentication for providing secure command link.
- System operates in two modes i) Clear mode ii) Secured mode. In clear mode encryption and authentication features are bypassed.
- Cross strapping between receivers and command decoders is provided.

- System provides isolated command interfaces to all main frame systems. Where ever Isolated interface is not feasible RS422 interface is used since it provides robustness against common mode noise.
- Heater interfaces is provided through opto-isolated Solid state switch, instead of mechanical relay & hence unlimited number of operations are provided
- It provides CMOS pulse commands and High voltage command pulses & levels.
- Provides 16 bit data commands, ORED data commands to Payload.
- Telecommand processor provides autonomy for control for all heaters by limit checking. The limits and sensor selection are programmable through command.
- TCP provides differential mode time tagged command execution facility, OBT based commanding, Command block ececution, Event based commanding, AOCE autonomy.
- System provides autonomy features like TCP autochange over, Mil 1553 bus change over , TM autochange over on failure.
- TMTC PIP packages are mission/project specific & shall support all conventional TC & TM interfaces to P/L. Command distribution to the Payload elements and payload heaters is carried out through PIP
- The TC & TM data communication between core & PIP is through MIL 1553 interface.
- Telecommand interfaces
    - 5V command interface received through opto coupler interface (2 line) by the sub systems.
    - Relay interface (29 V direct relay coil).
    - 1553 interface.
    - Heater interface through MOSFET switches
    - Rs 422 interface (for serial data transfer interface between TC & TM, TC & TTC-Rx)

1553 bus configuration

- GSAT-11 spacecraft has two 1553 buses namely TC 1553 bus & AOCE 1553 bus. TC is the bus controller for TC 1553 bus. Payload interface packages (PIP), power subsystem and TM subsystem are remote terminals (RTs) to this bus.
- Telecommand & Telemetry systems have Remote terminal for AOCE 1553 bus also which enables transfer of commands & acquisition of TM data to & from AOCE & RTs on AOCE bus.

- Telecommand system transfers command/data to systems on TC 1553 bus by BC to RT transfer and enables TM data transfer from Power and PIP packages to TM systems through RT - RT transfer.

Following table gives the RTs on TC 1553 bus:

No	Subsystem	No. of RTs	No. of active RTs	RT Addresses
1.	TMTC PIP-10 (South)	2	1	05_h
2.	TMTC PIP-20 (North)	2	1	06_h
3.	TC Core (non selected)	1	1	07_h
4.	Core Power Electronics- 10 (M & R)	2	2	01_h & 02_h
5.	Core Power Electronics- 20 (M & R)	2	2	03_h & 04_h
6.	TM-1 & 2	2	2	09_h & $0A_h$
7.	**Total**	**11**	**9**	

Table – 8.3: Tele-command Specifications

Input signal	PCM – NRZ L
Command bit rate	500 BPS
Format	CCSDS - AD/BD
Command/data length	1 Kilo byte
Spacecraft address	10 bits (CCSDS SCID)
Command frame length	4 octets – 1000 octets
Commanding modes	(i) Clear mode (ii) Encrypted & Authenticated

Number of ON/OFF commands	Core TMTC system - 560 commands PIP TMTC system - 1084 commands
Number of 16 bit Data commands	128 commnads
Command amplitudes provided	5V +- 5%, 29V+-1V, 70V (68V min)
Pulse width provided	64ms,128ms,256ms,512ms,1.5s,2.5s,4.5s,8.5s
Number of 16 bit data commands	128
Number of heaters	256 mainframe + 156 P/L
Number of TT commands, Resolution, range, Command width	255, 1.024Sec, 0-18hrs 4byte/upto to 64byte (H/W/MIL1553B)
Number of CCB,OBT commands, command width	255, 4byte/upto to 64byte (H/W/MIL1553B)
Number of Macro TT,EBC	16,24
AOCE events,capacity,command width	64,640commands, 4byte/upto 64byte (H/W/MIL1553B)
No of auto controlled heaters	All
Spurious Command Probability @BER=10^{-5}	3.9 X 10^{-7} at BER 10^{-5} for 1 command 2.87 X 10^{-5} at BER10^{-5} for 250 cmds / 1000 bytes data
Command Rejection Probability @BER=10^{-5}	2.58 X 10^{-26} at BER 10^{-5} for 1 command 10^{-22} at BER 10^{-5} for 250 cmds / 1000 bytes data

8.1.2 Salient Features of Telemetry System

- CCSDS TM system.

- System supports two formats (Simultaneous Normal & Dwell for TM1 & TM2).
- Programmable Telemetry – 24 bytes per frame embedded with Normal stream
- Two identical core packages (main & redt) are provided. Payload Telemetry is monitored by two PIP identical packages.
- Facility to dwell any 16 parameters (TM channels). Dwell facility in both TM1 and TM2.
- Core system hardware & PIP 1553 controllers are realized using Actel RTAX2000 FPGAs. 1553 Remote Terminal interface is realized in FPGA using IP core provided at Core system as well PIP systems.
- Core TM system is isolated from other systems in the spacecraft using differential interface as both LIVE and GND signals are taken for Analog and Digital Inputs. Also, 1553 Interface is used between Mainframe and Payload TM.
- Digital BPSK modulators are used for subcarrier modulation. Digital filters are used for filtering BPSK modulated data.
- Control signals to TC and corresponding RMU data from TC are through RS-422 interface.
- TM system ON/OFF provision.
- ESD protection to specific thermistor channels through transzorbs.
- TM system is having Remote Terminal (RT) for both AOCE and TC 1553bus. Each Core TM has two RTs, one for TC bus & another for AOCE bus.
- Telemetry interfaces
    - 1553 interface
    - Normal bit & RF bit monitoring
    - Thermistor interface
    - Transformer coupled interface between TM modulator and RF transmitter

Table – 8.1: Telemetry Specifications

Satellite ID	0x2E5 (1011100101'b)
Bit rate	2 Kbps
Sub-carrier frequency	32KHz for Normal, 128KHz for Dwell

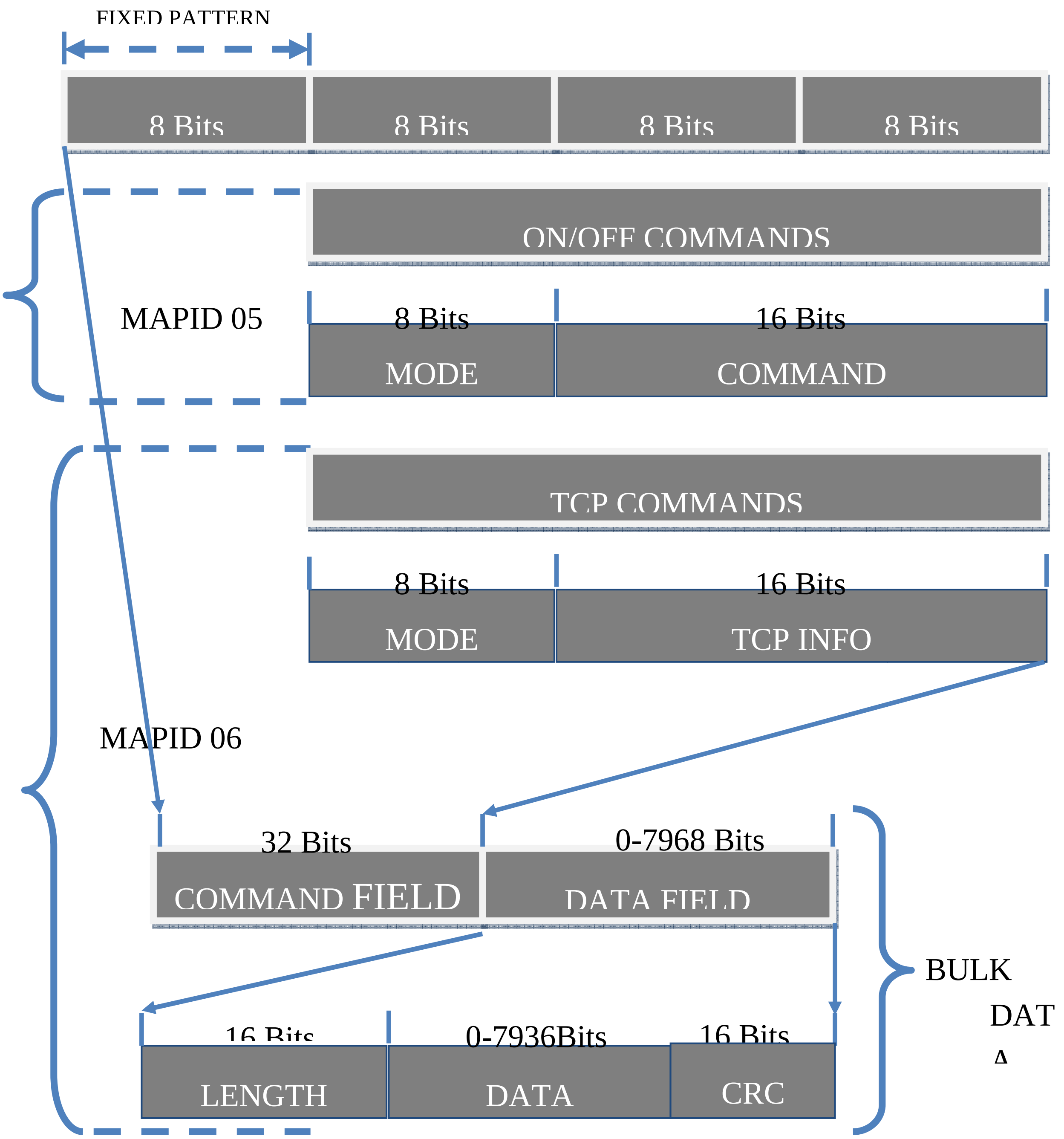
Number of Formats:	1.Normal Format (Embedded with PTM) 2. Dwell Format
Transfer frame length	256 Bytes
Frame rate	1.024 sec
Frame sync code	32 Bits (1A CF FC 1D)
No. of frames	32
Frame ID	5 Bits
On board time	5 Octets (8 m sec. resolution)
No of Virtual Channels	Four
No of Master Channels	One
Monitoring Input	
Analog	-5V to +5V
Digital Bi-level Bits	0 or 5V
Switch status monitoring	Open or Close
Thermistor	10K Thermistor
1553 Parameters	All RTs on AOCE and TC Bus
Output to Transmitter	Randomized PCM-NRZ (L)–PSK, 4Vp-p ,2V

8.1.3 Command code Format

BIT No.	DESIGNATION	REMARKS
B0 to B7	Fixed pattern	Dec1-11$_h$, Dec2-12$_h$, (core systems) PIP10=10$_h$, PIP10=20$_h$ (PIP systems)

B8 TO B15	Mode address	**With MAP 05** 00- Nominal on/off commands (upto 512ms depends on B20,B21) 01 -On/off pulse width 1.5s 02 -On/off pulse width 2.5s 03 -On/off pulse width 4.5s 08 - On/off pulse width 8.5sec 40 –High level on off commands 64ms **With MAP 06** 10-FF TCP modes
B16 to B19	Card ID	0-F
B20 , B21,	Pulse width for ON/OFF Commands	00 - 64ms 01 - 128ms 10 - 256ms 11 - 512ms
B22 to B24	Not used	000
B25 to B31	7 bit command address	00-7F

MAP05 AND MAP 06 COMMAND FORMATS



8.1.3 On-board Autonomy Functions

TCP provides autonomy features for thermal management, FDIR, TT; CCB based command execution, Battery Safety logic, MACRO command execution, 1553 B Data/command transfer and Telemetry reception to or from the designated subsystems respectively. TCP is implemented using

MAR 31750 Microprocessor with 128Kx16 SRAM, 64Kx16 PROM and RTAX 2000 FPGA (implements the glue logics).

The main features of TCP are:

- ✓ Command Processing
- ✓ Thermal Management
- ✓ Differential Time Tag Command Execution
- ✓ Configurable Command Block Execution
- ✓ OBT Based commanding
- ✓ Remote programming
- ✓ Safe mode operations
- ✓ MACRO Block Execution
- ✓ Command/ Data transfer through 1553B interface (1553B RT) for AOCE
- ✓ 1553B BC functions : Command/ Data transfer to Payload interface package(PIP), Telemetry acquisition scheduler, Telemetry data processing and extraction form TM RT
- ✓ Telemetry Events autonomy functions
- ✓ Battery Safety logic
- ✓ Diagnostic features
- ✓ AOCE event autonomy functions
- ✓ TM data transfer to AOCE
- ✓ TCP Auto change over
- ✓ Controlled TCP Reset
- ✓ Telemetry CRC check

9 TTC- RF

9.1 Introduction

The GSAT-11 TT&C (RF) system is configured with C band TTC for transfer orbit and on orbit operation. It comprises of 2 numbers of Transmitters, 2 numbers of Receivers, 2 numbers of ku beacon modulator and the associated antenna System. Antenna system consists of an Omni antenna for both the up and down links and additional Global beam antenna for downlink.

Following are the uplink and down link frequencies:

Tx	Rx
4194.864 MHz	6415.00 MHz
4198.560 MHz	6417.160 MHz

The onboard TTC-RF system configuration performs the following functions:

- Transmitters should downlink the spacecraft telemetry data to control stations in phase modulated format. The signal input from Base band system to the RF transmitter is PCM/PSK at sub carrier frequencies of 32 kHz and 128 kHz with 2 kbps data rate.
- Receivers should receive the uplink and provide input to the command decoders for command execution. The onboard receiver should provide the command data at the rate of 500 bps and the required clocks to the command decoder onboard. The demodulation scheme should be FM/PSK/PCM.
- The transponder should demodulate and modulate the ranging tone from/to the earth station for spacecraft ranging information. The demodulation at receiver is FM and the modulation at transmitter will be PM.
- The transponder at 6.4 / 4.2 GHz should demodulate and modulate the ranging tone from/to the earth station for spacecraft ranging information. The demodulation at receiver is FM and the modulation at transmitter will be PM.
- The antenna and related passive elements connected to the receivers and transmitters should provide the required antenna pattern coverage for the GSAT-11 mission such that the LEOP and on orbit operations of commanding, ranging and health monitoring of GSAT-11 carried out from major and supporting network stations will have sufficient RF link margin .

- The TTC-RF subsystem should provide a phase modulator at 535 MHz for third level TM redundancy with Ku-Beacon. The TM base band at 2 kbps with 128 kHz sub carrier-PCM/PSK is the modulation input to PM modulator.

9.2 System configuration

The overall block schematic of the GSAT-11 TTC RF System configuration is shown in Fig. 9.1

Figure – 9.1: Block Schematic of TTC RF System

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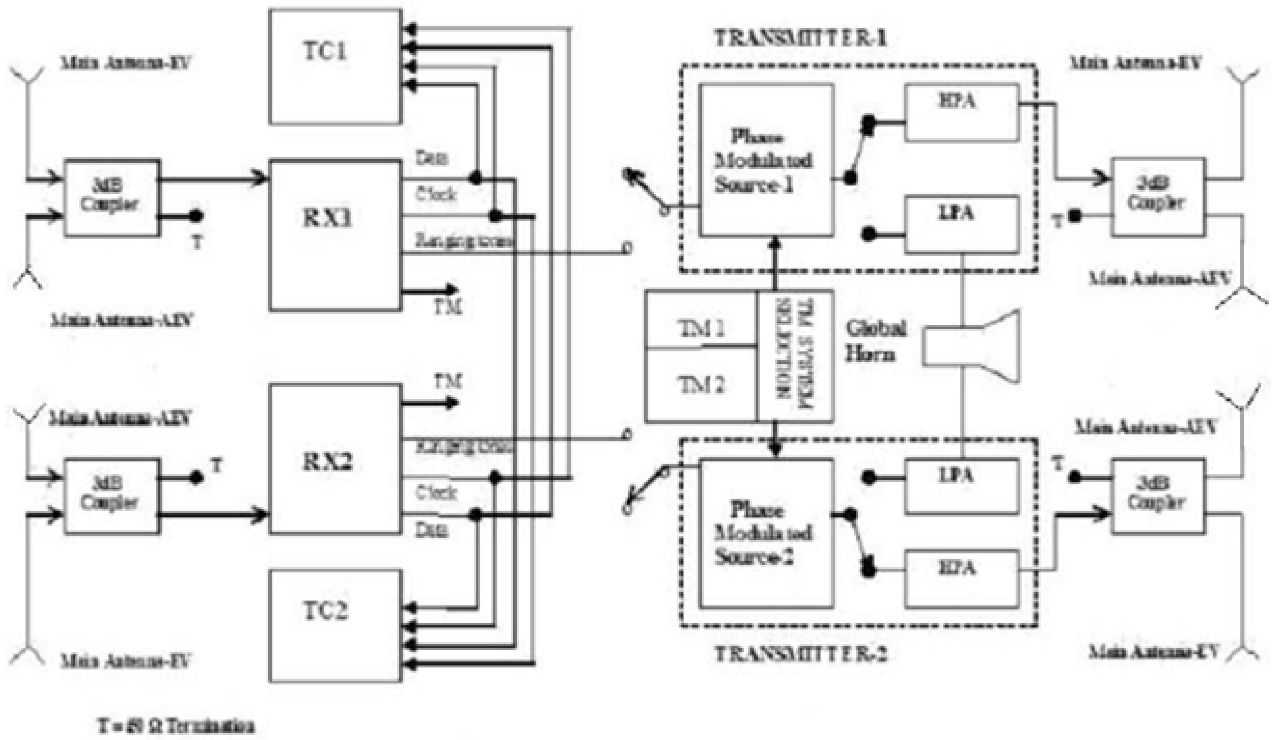


The receivers are kept ON continuously thus providing hot redundancy whereas any one of the TM transmitter is switched ON or OFF as per the requirement of the mission. The transmitters and receivers operate in different frequencies and thus provide protection against interference in addition to hardware redundancy. The command channel outputs of the receivers are fed to their respective decoders and also cross strapped with other TC decoders and the ranging channel outputs are fed to their respective transmitters without cross strapping. The ranging signal input to the transmitter can be disconnected by Ranging ON/OFF command to the Transmitters.

The phase modulated transmitters operate in two modes, high power and low power mode, the selection of which is done by command. GaAs FETs are used as power amplifiers. The Low Power output is 26.0 dBm whereas the High Power output is 35 dBm.

The telemetry transmitter TX-1 and TX-2 receives the normal and dwell data at 32 KHz and 128 KHz from the TM Encoder package and these signals phase modulates the 4.2 GHz RF downlink carrier.

The phase modulator along with Ku band beacon [(at beacon frequencies of 10701 MHz (in LH) & 10701 MHz (in LV)] is used to transmit the on-board telemetry data in Ku band. This modulator acts as a third level redundancy for the telemetry link.

9.2.1 TTC Receivers

The Command and Ranging receiver for GSAT-11 is a double super-heterodyne type with the capability to demodulate PCM/PSK/FM signals. The receiver accepts signals at the pre-assigned C-band frequency and provides data, clock and gated lock signals in differential form to the command decoder and ranging tones in differential form to Telemetry and Ranging Transmitter. Telecommand outputs are provided to TC decoder using RS422 interface. Ranging outputs are provided to transmitter using transformer coupled interface. The receiver incorporates FM demodulation in analog domain and PSK demodulation in digital domain. There are two receivers operating in hot redundancy and the receivers are always connected to the spacecraft “Omni” antenna system without incorporating any switch in the path. The receiver is built around sub-modules, namely, C-band RF front end, IF section, FM demodulator, PSK demodulator and bit synchronizer, and local oscillator generation section, interface section at base-band. Receiver uses in-house developed DC-DC converter. DC-DC converter PCB housed in a suitable aluminum carrier is housed inside the receiver. Below table gives the specifications for C band Rx:

Table 9.1 TTC Receiver Specifications

S.NO.	Parameter	Specification
1	Frequency of operation	6415 MHz , 6417.16MHz
2	**Command channel**	
	Modulation	FM /PSK / PCM (NRZ-L)
	Frequency Deviation	±400KHz
	Subcarrier frequency	8 KHz
	Bit rate	500 bps

	Preamble	512 bits
	Dynamic range	-110 to -60 dBm
	BER @ -110 dBm	1 x 10^{-5}
	Output signal	Data, clock, lock
3	**Ranging channel**	
	Modulation	FM
	Frequency Deviation	$\pm$400KHz
	Dynamic range	-103 to -60 dBm
	SNDR @ -103 dBm	60 dB-Hz
	Output type	Differential
	Ranging tones	27.777 KHz (Major Tone), 22 KHz, 4 KHz (Minor Tone)
4	**Spacecraft interface**	
	DC power consumption	10W (Typical) @ 70 V
	Size	284 mm X 222mm X 91.5mm
	Mass	2.5 Kg (Typical)
	DC power connector	9 pin (plug)
	TMTC connector	37pin (socket)
	RF connector	SMA (Jack)

9.2.2 TTC Transmitters

The design of TTC transmitter derives heritage from INSAT-4A/INSAT-4B/INSAT-4C. Raw Bus voltage is 70 V here where as it is 42.5 V in heritage transmitter. Ranging On/Off command pulse amplitude has been changed to 29 V. Transmitter On/Off Command has been changed to MOSFET type command with Opto Isolated Interface. The transmitters are powered by a built-in DC/DC converter which provides the required voltages for the operation of the transmitter from the raw bus voltage. Provision is incorporated for monitoring the availability of +8 V supply for the GaAs FETs.

Following Table provides the specifications of C band Transmitters:

Table 9.2 TTC ransmitter Specifications

S.NO	Parameter	Specification
1.	Frequency of operation	4194.864 MHz, 4198.560 MHz
2.	Modulation	PCM/PSK/PM
3.	Input signal	PCM/PSK, 4V P-P
4.	Sub Carrier Freq	128 KHz, 32 KHz
5.	Bit rate	2 Kbps
6.	Modulation Index	0.9 Radian
7.	Power output	≥ +26 dBm
8.	DC power consumption	23W Max @ 70 V
9.	Size	242x 161x 108 mm
10.	Mass	2.2 Kg (Typical)
11.	Temp range	Tx turned on at -40 °C, operating range: -25 °C to +55 °C

9.2.3 Ku Beacon modulator

The phase modulator along with Ku-Band beacon is used to transmit the on-board telemetry data of GEO satellite in Ku-Band. This modulator acts as a third level redundancy for the telemetry link. The modulator is integrated in the Ku-Band chain, which is normally used for tracking purpose. Phase modulation is carried out at 535 MHz, later the signal is multiplied in the beacon to Ku-Band i.e. 10.7 GHz. A block schematic of the modulator is shown.

The modulator consists of two similar phase modulator circuits Modulator-1 and Modulator-2 which are connected to Ku-Beacon-1 and Ku-Beacon-2, respectively. The specifications of the modulator are given in Table. The modulator mainly consists of a UHF amplifier, phase modulator and a relay with associated circuit as shown. The input to the modulator is -10 dBm at 535 MHz. The UHF

amplifier uses a BJT (AT-42070) and provides a gain of around 13 dB. The amplified carrier is modulated with 128 kHz TM subcarrier signal. The phase modulator is of reflection type and uses a quadrature hybrid and four varactor diodes. The telemetry signal phase modulates the RF signal and provides a modulation index of 0.045 radians.

Table 9.3 Ku beacon modulator functional Specifications

S.NO	Parameter	Specification
1.	Frequency of operation	535MHz
2.	Modulation	PM
3.	Modulation index	0.9 radians (at Ku-Band)
4.	Frequency response	300 Hz 150 kHz
5.	Index variation (over frequency range)	± 10 %
6.	Modulation linearity	± 2 %
7.	Input impedance (modulation)	10 kΩ for telemetry line
8.	Input / Output impedance	50 Ω
9.	Input return loss	< -15 dB
10.	DC supply	+ 15 volts ± 5 %

9.2.4 Antenna configuration

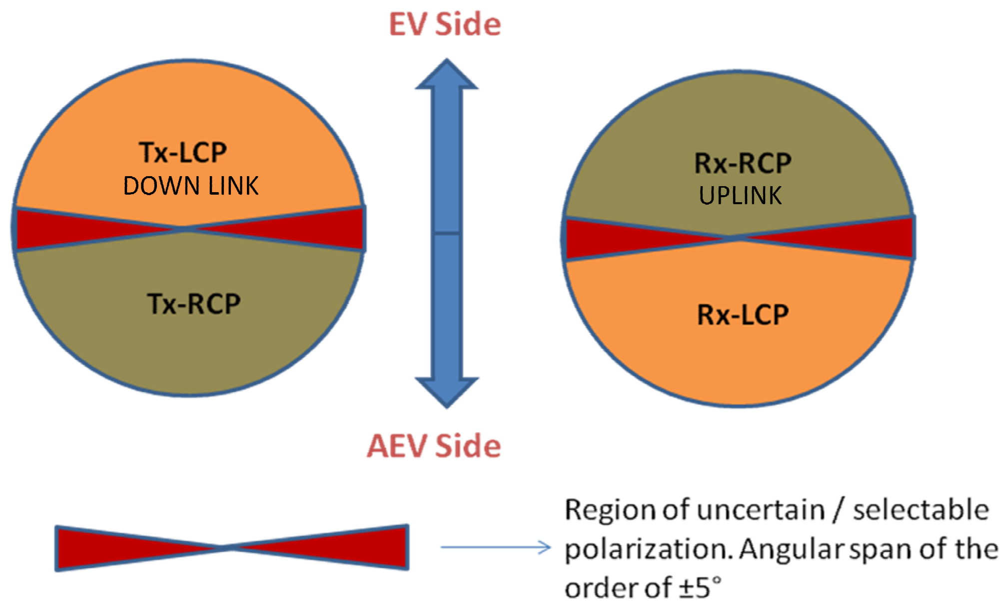
The Antenna system consists of an Omni antenna for both the up and down links and additional Global beam antenna for downlink. The Omni antenna system consists of two Main antennas on EV and AEV mounted suitably on the spacecraft to obtain the required coverage for both transfer and in-orbit operations. Main antenna is a fractional turn quadrifilar helix chosen considering the wide beam width requirement, gain, polarization and weight characteristics. Main (EV) and main (AEV) antennas are fed in 1:1 ratio by a suitable 3dB coupler. Dedicated main EV & AEV antennas are used for each transmitter and receiver. Global beam antenna is a Dual Mode Conical Horn giving the required beam coverage of 17°. The receivers are always connected to the omni antenna system whereas the transmitters are connected to either omni or global antenna depending on the requirement. The scheme is such that the high power mode is connected to the omni and the low power to the Global antenna. The selection of Low power / High power mode is done through a co-axial RF switch, by command.

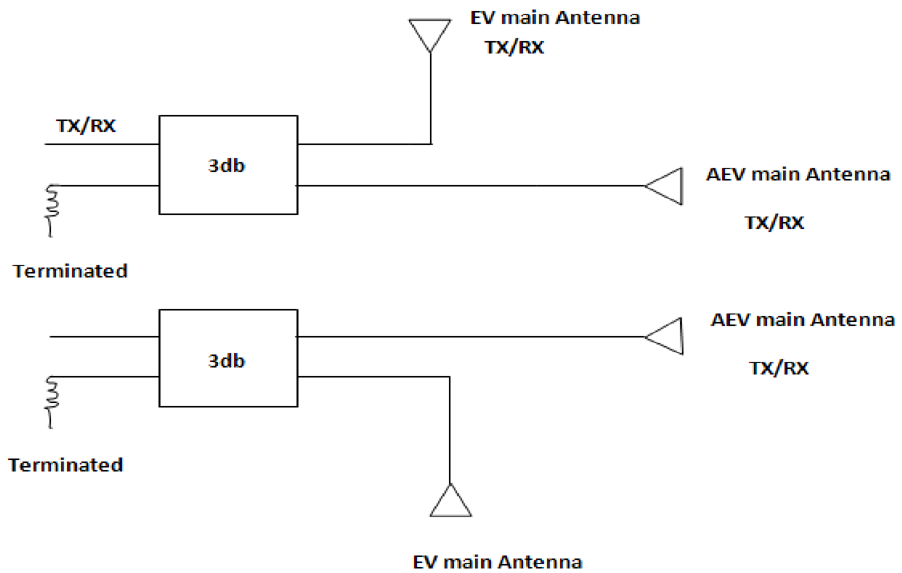
The transmitters and receivers are interfaced with their respective antenna systems through couplers. The two chains can be operated, if required, for simultaneous ranging and commanding

operations. In this mode, one uplink carrier is used for commanding while the second uplink carrier along with the transmitter is used for ranging operations.

The Antenna system coverage requirement is shown in Figure – 9.2. The Antenna system configuration and the feeding scheme is shown in figure – 9.3.

Figure – 9.2: TTC – Omni antenna Coverage





The Omni pattern is achieved by the combination of four antennas (two each-DL/UL) mounting on two opposites of the spacecraft with orthogonal circular polarisation. In this configuration each

element provides ± 90° coverage with one antenna operating in Right Hand Circular Polarisation (RCP) and the other in Left Hand Circular Polarisation (LCP). The mounting ensures the complete 360° radiation coverage for both transfer and on orbit operations using orthogonal circular polarization.

Following are the specifications of Antenna system:

Specifications of EV Main Antenna

- Type : Quadrifilar Helix Antenna
- Uplink Frequency : 6410.896 MHz, 6412.912 MHz,
- Downlink Frequency : 4186.848 MHz, 4190.976 MHz
- Radiation coverage (-4 dBi dB level): ±90 deg.
- Uplink Polarization : RHC
- Downlink Polarization : LHC
- Return loss : Better than 15 dB

Specifications of AEV Main Antenna

- Type : Axial mode Helix
- Uplink Frequency : 6415.000 & 6421.480 MHz
- Downlink Frequency : 4194.000 & 4199.280 MHz
- Radiation coverage (-4 dBi dB level): ±90 deg.
- Uplink Polarization : LHC
- Downlink Polarization : RHC
- Return loss : Better than 15 dB

Specifications of Global Horn Antenna

Frequency	4187.52 & 4189.344 MHz
Return loss Bandwidth	±15 MHz
Beam width (Nominal)	17 deg.
Gain	18 dBi min.
Polarization	Dual circular RHC / LHC

Cross polarization (on-axis)	25 dB Min.
Output connector	SMA (F)
Return loss	Better than 15 dB

10 Power

10.1 Introduction

GSAT-11 is a high power Ka x Ku band Communication satellite with an electrical power requirement in the order of 10 KW. The Power System configuration for this satellite consists of:

- 5 solar panels per wing, populated with Multiple Junction solar cells for power generation
- 2 nos. of 180 Ah, Lithium Ion battery for energy storage to support 9KW of eclipse power
- Single fully regulated 70V power bus regulated by Fixed Switching String Shunt regulator (FS3R) during sunlit and Battery/Battery Discharge Regulator (BDR) during eclipse.
- Bus Power distribution to subsystems through bus bars and dedicated fuse distribution modules
- A dedicated current sensor modules for sensing Battery Charge/discharge currents and Payload currents
- Electro Explosive Device Powering unit to power the Squibs

10.2 System Configuration

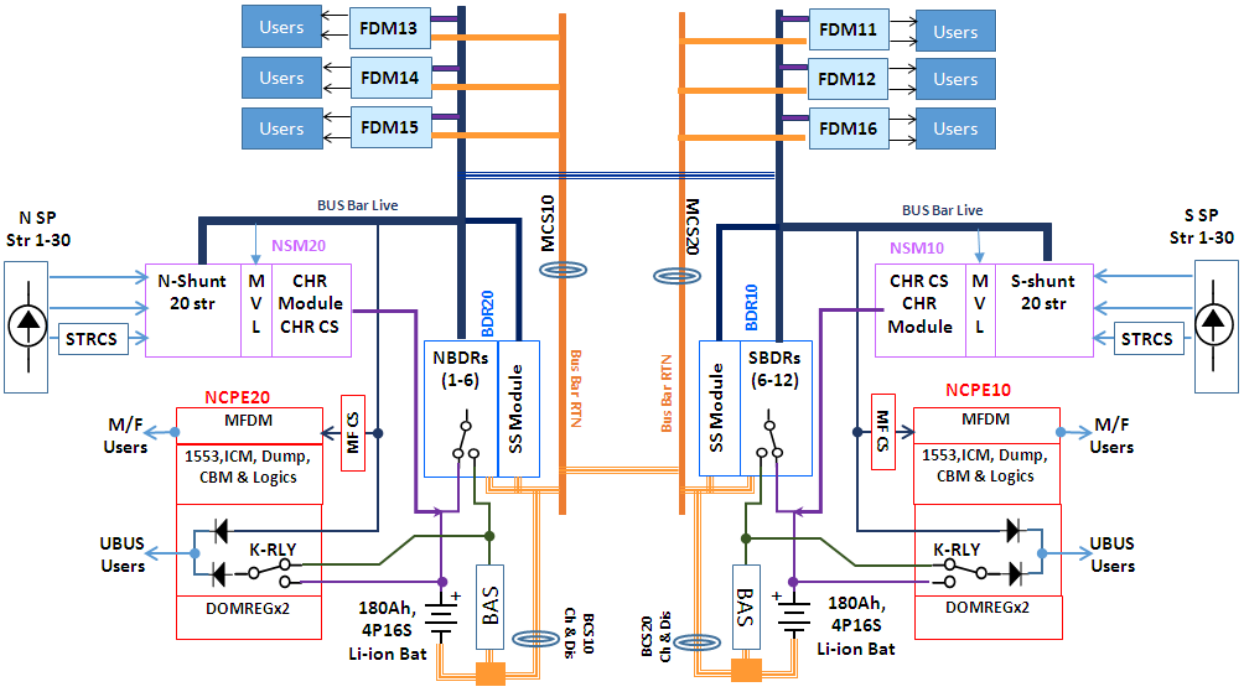
The power system is designed for generating and distributing approximately 14KW of power which meets the payload and bus system power requirement for the entire mission life.

Table – 10.1: Bus Specifications

Bus Voltage	Fully regulated 71 V bus (Sunlit : 71±0.05V :: 69–70V : Eclipse)
Charger strings	4 per battery with Cross strapping
Solar array power strings	29 power strings per wing (converted to 40 strings at shunt)
Payload Current Sensor	0 to 150A
Battery charge/discharge current sensor	-30 to 180A

Battery UVP trip level	3.0 ± 0.05 V for any cell
Battery Over charge protection	4.2 ± 0.05 V for any cell

The following figure gives the Power System Block Diagram



The Primary power is provided by two wings of sun tracking and deployable solar array, populated with multi-junction solar cells for the optimum power generation. Solar array consists of 5 panels in T-configuration on each side catering to the total generation of 13.6KW (EOL-EQ). The energy storage system consists of two Li-Ion batteries of 180AH each. The eclipse and peak power requirement are with SAFT VES180 Li-Ion cells in 4P8S and 4P8S configuration.

Power is routed from the two winged solar array to the two shunt modules which are housed in the bus module. Shunt modules take the input from MVL to provide fully regulated 70V output. The output of two modules will form a common 70V bus. However in eclipse, BDR takes the input from Battery and boost the voltage to bus voltage of 70V thereby making the bus fully regulated. The bus is distributed to the users through the Fuse Distribution modules.

10.2.1 Solar panels

GSAT-11 solar array consists of two wings of rigid, deployable and sun tracking solar panels. Each of the deployable wings is made up of 5 panels (each panel size is 3300 mm X 2100 mm) and a 'T' shaped yoke. The solar array is designed to generate electric power to meet the spacecraft requirements during transfer orbit phase and till the end of 15 years in a Geo-stationary earth orbit (GEO). The solar panel substrate is similar to those of ISRO-heritage INSAT-3, INSAT 4 and GSAT series consisting of aluminium honeycomb core sandwiched between CFRP face skins with co-cured Kapton insulator on cell layup side. The solar array is configured to have multi-junction cells on all the ten panels.

Table – 10.2: Solar Panel Specifications

Array type	Two winged, sun tracking, deployable and rigid
Solar cells used	Advanced Triple junction (ATJ) cells
Array Power	1560 Watts @ 70V in TO, GTO drift orbit and 13.6KW in on-orbit, EOL (Equinox)
Designed life	15 years (minimum)
Bus Voltage	69 - 71V
Array temperature	45°C to 55°C in O.O.EOL
Array orientation accuracy	± 0.5°
Total solar array area	69.3 m^2
Total number of panels	10
Number of panels per wing	5
Dimension of the panels	3.3m X 2.1m
No. of sun sensors (SPSS)	4
Total number of strings	30 solar array strings per wing grouped to form 21 strings at the shunt inside the S/C.
No. of circuits in parallel	250 per wing

Charger strings	4 per Battery
Solar array weight	230 Kg. (estimated excluding mass of mechanisms)
Substrate manufacturer	Composite structure configured by CMSE, VSSC

10.2.2 Battery

GSAT-11 spacecraft requires a power support of 8.2 KW during eclipse season for a maximum duration 1.2 hours per day. GSAT-11 energy storage system consists of two 180 Ah (nameplate capacity) lithium-ion batteries that can support the requirements. Each battery has 64 VES180SA cells in 4Px16S configuration with a maximum depth of discharge (DOD) of 55% of nameplate capacity. The 4P16S battery is divided into two modules of 4P8S, for ease of handling. Cells for batteries were procured from SAFT, France and the batteries are designed by ISAC. The two batteries are located in east and west battery deck. Charger strings will be used for on orbit battery charging.

The following table gives the operational specification of a battery:

Table – 10.3: Battery Specifications

Battery type	Lithium Ion
Cell type	SAFT VES 180SA
Cell Capacity	45 Ah
No. of cells in each battery	4Px16S (64 cells/battery)
No. of batteries used in the spacecraft	2
No. of modules per battery	2 * 4P8S
Temperature range at the base	10 to 30°C (equinox) 10 to 15°C (solstice)
Storage temperature range	0 to +10°C
Handling temperature range	30°C (max.)
Gradient within battery (measured at identical locations)	< 5°C
Gradient within battery (equinox) (measured at identical locations)	< 5°C
Eclipse load	8200 W at battery end
Max depth of discharge(DOD)	54% of nameplate
Maximum DoD (with one-cell failure)	59% of nameplate

Life (operational)	15 years
Mass per battery	96 kg (max.) per battery
Overall dimensions of battery (including Thermal) (L*W*H)	604 x 350 x 275 mm^3
Battery dump load scheme	Across 40 Ω resistor network

10.2.3 Power Electronics

Power electronics for GSAT-11 is designed for control of the power generation, storage and distribution of power to the various subsystems. The main elements of the power electronics are:

- Shunt regulators (FS3R)
- Bus formation and distribution
- Battery control circuits for
  - Charging through charger strings
  - Discharging through BDR
  - Battery protection circuits
  - Battery dump
- Battery ,Solar array , mainframe , payload current sensors
- Converter regulators for domestic-use
- Electro explosive devices powering scheme
- Interfaces for all digital and analog telemetry parameters through 1553

Power is routed from the two winged solar array to the two shunt modules which are housed in the bus module. Shunt modules take the input from MVL to provide fully regulated 70V output. The output of two modules will form a common 70V bus. However in eclipse, BDR takes the input from Battery and boost the voltage to bus voltage of 70V thereby making the bus fully regulated. The bus is distributed to the users through the Fuse Distribution modules. Power electronics comprises of FPGA based core power electronics, Battery Discharge Regulator (BDR), shunt, EED, Payload current sensor and battery 1 & 2 charge/discharge current sensors.

10.2.3.1 Individual Package Details

Battery Discharge Regulator (BDR)

During sunlit condition, the shunt regulators regulate bus by regulating the solar array power. During eclipse, battery needs to supplement the excess power required. Normally battery voltage will be lower than the bus voltage. The battery voltage needs to be boosted to the bus voltage to maintain the bus regulation.

Hence a Battery Discharge Regulator (BDR) is employed to maintain the bus regulation during eclipse or peak power requirements to avoid the off-optimal operation of the solar array and consequent over sizing of battery and the extra charger power required from the Solar Array.

BDR is a Boost Regulator, which regulates the bus voltage in-spite of the variations in the battery voltage. This results in 3 to 4% improvement in the overall efficiency of the user DC-DC and TWTA converters.

Specifications:

Type (Topology)	:	O/P Regulating boost
O/P voltage	:	70±1.5V
I/P voltage	:	45 - 67V
No. of modules	:	6 (5/6 modules on each side with hot redundancy)
O/P power	:	1KW per module

Shunt package (Modular)

The solar array output voltage is regulated to 70 V during sunlit period by use of shunt regulators placed inside the spacecraft. There are 30 strings per wing. Two stacks of 2 shunt regulator modules each will receive power from solar array to regulate the bus voltage. The output of all the modules will form a common bus. Since 60 numbers of 10A SADA slip rings are used, 30 strings per wing are available to meet the required power. Capacitor banks will be housed in BDR modules near the bus formation point to take care of bus ripple.

The concept of ‘Fixed switching string shunt Regulator (FS3R)’ is chosen which employs single majority voting logic (MVL) to provide a fail-proof bus voltage error. The bus voltage is regulated to 70V by switching one string. Remaining shunt strings are either ON/OFF depending on the load conditions and whether the MVL output is above or below the switching string window. A redundancy exists for the switching string. As the load is increased, the MVL error moves towards positive direction, includes the required number of solar array strings. If the load on the bus is beyond solar array capability, the BDR is included.

FPGA based Core power Electronics (CPE):

Core power electronics performs control, monitoring, TM processing and powering of whole power electronics. This package is modular, stackable tray type combining the functions of Battery

Interface Module (BIM) and existing Core power package. This package incorporates domestic regulator, FPGA based TMTC,1553 interface , Mainframe power distribution , Mainframe current sensor , battery dump, k-relay ,U bus formation, battery individual cell monitoring and battery protection circuits like Under voltage logic(UVP) etc.,

EED Powering unit

The scheme is essentially same as all INSAT missions and meets the safety requirements of the launcher, the current needed for reliable operation of squibs (Fusistor design shall take care of higher battery voltage) and necessary TM, TC & GC interface requirements. These EEDs are used for pyro triggered events of deployments and fuel/oxidizer valves.

GSAT-11 uses several deployment mechanisms and pyro operated propulsion elements. These Electro Explosive Device (EED) events require battery to power the squibs. EED powering is by tapping at the 10th cell of battery (like GSAT-6), Arm bus is on 70V.

Fuse Distribution Module

Dedicated fuse distribution modules (FDM) are designed for the first time. 2 types of FDM's are realized to distribute bus through source end fuses to payloads and receivers. Totally 6 FDM's are used in GSAT-11. 2 numbers are on North payload panel, 2 numbers are on south payload panel to service bus to payload elements. 2 are on EV bottom to service bus to receivers. Distributes the raw power from BUSBAR to receivers and payload systems.

Two FM12 fuses are paralleled to distribute power.

For 5A current requirement, two FM12 10A, fuses are paralled

For 6A & above, two FM12 15A, fuses are paralled.

High Resolution Current Sensor Module

MCS and BCS are high resolution current sensors which can measure larger range of currents with higher resolutions using only two analog channels. The concept of one channel indicates current in smaller range and other channel indicates the range in which current is being measured. This sensor provides 15 times better resolution than single channel sensors.

MCS package is used to measure the current loaded by the payload and its components. The MCS consists of 2 cards viz:-MCS 10-0-01 and MCS 10-0-02. The unidirectional sensor is designed to

measure currents from 0A to 150A. This sensor works only in one direction and provides a raw TM voltage of 0 to -10V for full range of current to the next card, the high resolution card.

However, the BCS package is used to measure the Battery discharge and charge currents. As the current flow is bidirectional, the current sensor used here is a Bi-directional Current Sensor (MCS10-0-03) along with the same high resolution card as used in MCS package. The sensor card is designed to measure the current from -30A (charge current) to +150A (discharge current).

Table – 10.4: List of Power System Deliverables

PACKAGE	NUMBER OF MODULES
BDR+SS (BDR 10/20)	7 modules per package{BDR(6.nos)+SS(1 no)}
SHUNT MODULE (NSM 10/20)	7 modules per package
CORE POWER ELECTRONICS (NCPE 10/20)	8 trays including 1553 (DC/DC TRAY+7)
EED (EED 10/20)	3 CARDS package with 22 relays in base plate
FUSE DISTRIBUTION MODULE (FDM 11/12/13/14/15/16)	2 for north payload panel 2 for south payload panel 1 on Extended north 1 on Extended South
PAYLOAD CURRENT SENSOR (MCS 10/20)	1 for north payload panel 1 for south payload panel
BATTERY DISCH CURRENT SENSOR (BCS 10/20)	2 CS for BAT-1 & 2 currents
Current Sensor Reset Box	

50W Dc-Dc Converters	25
15W Dc-Dc converter	10

Table – 10.5: EED Events

Event No.	Event name	Number of main squibs	Number of Redt squibs	Type of pyro
1	Fuel and Ox line pyro valve open	2	2	NC pyro
2	Pressurant pyro valve open	1	1	NC pyro
3	Pr. Reg. bypass pyro valve open	1	1	NC pyro
4	LAM Pyro valves close for Ox & Fuel	2	2	NO Pyro
5	Primary Deployment of South Solar Array	1	1	Cable cutter regular
6	Secondary South Solar panel deployment (Panel 4&5)	1	1	Cable cutter regular
7	West Antenna-1 Deployment	1	1	Cable cutter regular
8	West Antenna - 2 Deployment	1	1	Cable cutter regular
9	Primary Deployment of North Solar Array	1	1	Cable cutter regular
10	Secondary North Solar panel deployment (Panel 4&5)	1	1	Cable cutter regular
11	East Antenna-1 Deployment	1	1	Cable cutter regular
12	East Antenna-2 Deployment	1	1	Cable cutter regular

Table – 10.6: Signal Slip Ring allocation

Sno	Signal type	Number of signals	Number of wires (Live + Return)	1 A type	2.5A type
1.	Solar panel microswitches	6	6 live + 2 Rtn	8	

2.	Hold down monitoring for Side solar panel deployment	1	2	2	
3.	Side solar panel pyro ground	1	1	1	
4.	Hinge PRT	5	10	10	
5.	Damper PRT	1	2	2	
6.	Solar panel rear side PRT	3	6	6	
7.	SPSS data	2	6	6	
8.	Solar panel substrate ground	5	2	2	
9.	Yoke ground	1	1	1	
10.	SADA shaft thermistor	1	2	2	
11.	SADA flange thermistor	1	2	2	
12.	N SP01 Edge/S Yoke Edge	1	2	2	
13.	Pyro cmd for Side solar panel deployment	2	4	-	4
14.	Spares			2	nil
	TOTAL			**46**	**4**

11 Attitude and Orbit Control System

11.1 Introduction

The attitude and orbit control system (AOCS) for GSAT-11 Spacecraft uses the body stabilized momentum biased system with momentum/transverse momentum wheels for synchronous orbit operations and 3-axis attitude control system using thrusters in Transfer Orbit. The synchronous orbit control system specifications are arrived at based on the pointing requirements of communication antennae, whereas the transfer orbit specifications are derived considering the launch vehicle and Spacecraft attitude maintenance requirements during orbit raising mode.

The communication Payload consists of (16 x 2) user spot beams in Ku-Band and (4 x 2) hub beams in Ka-Band. There are 4 reflectors; each reflector caters to (4 x 2) Ku beams. Each beam has a width of 0.76° and it is required to maintain the beam pointing within ±0.05° to meet the pointing error loss to 1dB as well as to ensure beam to beam isolation.

The pointing requirements of the antennae are realized through the closed loop RF tracking. The on-board tracking system will track the beacon transmitted by the ground station to drive the antenna in Azimuth and Elevation. There is a one RF sensor and two drive motors for each one of the antennae. The processing of the RF signal is done by a single Tracking receiver, catering to each antenna sequentially. The AOCS functional block diagram is shown in Figure – 11.1.

11.2 Performance Requirements

The Platform performance Requirements of GSAT-11 is as follows:

Yaw **$\pm$ 0.2 ^{0}**

Roll **$\pm$ 0.15 ^{0}**

Pitch **$\pm$ 0.15 ^{0}**

The antenna pointing specifications are ±0.05° about all 3 axes for (16 x 2) beam configuration.

The main contributing factors for antenna pointing errors are:

- ✓ Spacecraft sensors alignment errors
- ✓ Thermal distortion errors arising from antenna reflector due to shadow induced temperature gradients.

- ✓ Orbit perturbation errors due to deviation of spacecraft orbital parameters from nominal.
- ✓ Attitude control errors as a result of inherent attitude control equipment inaccuracy and control system performance characteristics.

11.3 AOCS Configuration

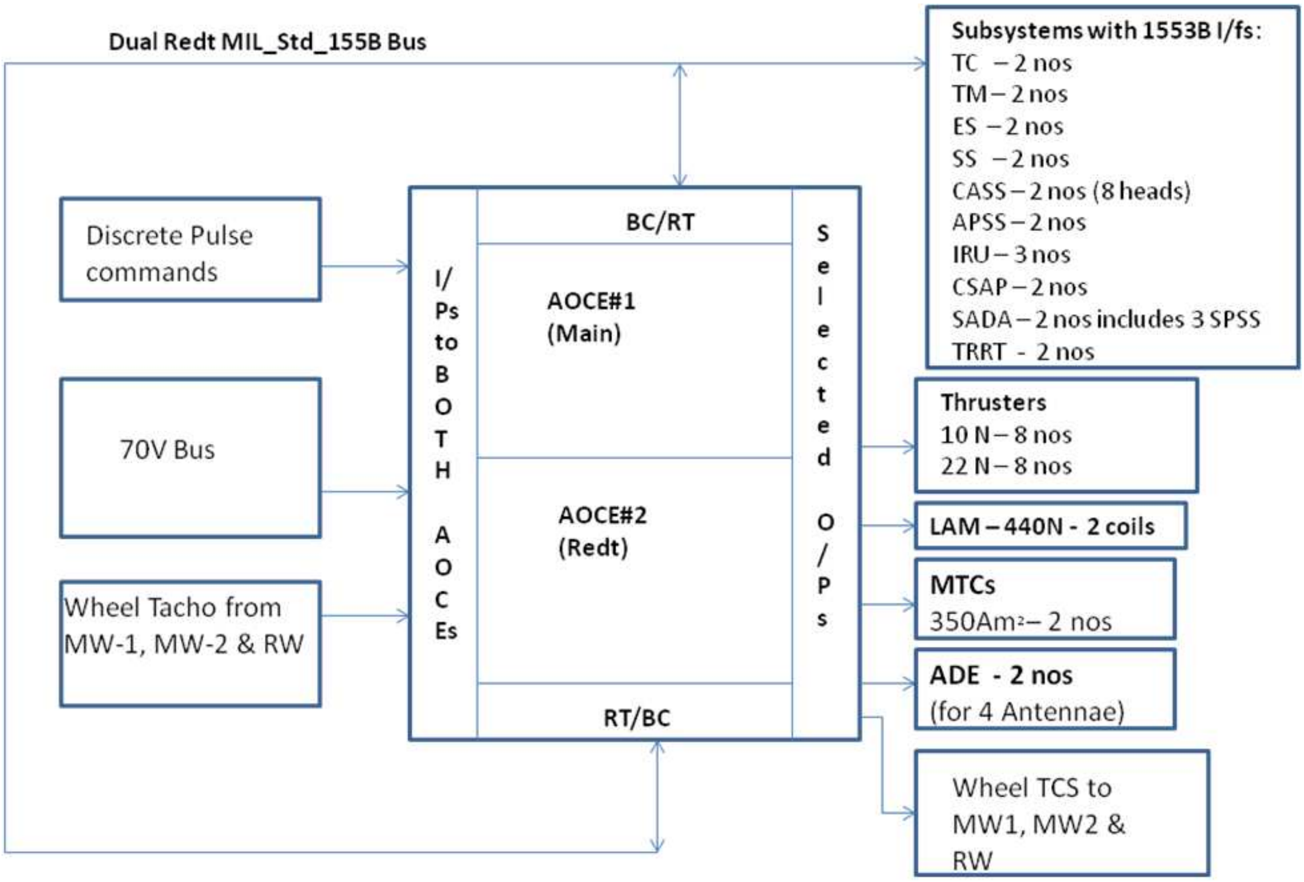
11.3.1 Introduction

The primary objectives of Attitude and Orbit Control System (AOCS) is to provide stable platform to meet the pointing requirements of the communication payloads, to maintain the spacecraft in the allotted Station-Keeping window as well as to minimize the interruptions in the services in the event of any attitude loss.

The Attitude and Orbit Control System (AOCS) uses the body stabilized momentum biased system with momentum/reaction wheels to provide a stable platform for communication. Together with the propulsion subsystem, AOCS provides capability of 3-Axis attitude control using thrusters in the transfer orbit, as well as orbit raising and fine orbit corrections.

Attitude and Orbit Control Electronics (AOCE) receives attitude information from various attitude sensors, does the processing in accordance with the control algorithms and the chosen mode of operation and generates the control signals for the actuators. AOCE interfaces with attitude sensors and actuators to carry out the above functions. AOCE also interface with Telecommand and Telemetry (TTC) to receive the commands and provide health monitoring. The block diagram of AOCE and its interface with other subsystem is shown in Fig.11.1. The three major components in the AOCS subsystem are Sensor, Attitude and Orbit Control Electronics and the Actuators.

Figure – 11.1: Block diagram of AOCS



11.3.2 Attitude & Orbit Control Electronics

AOCE is a microprocessor based system which interfaces with various subsystems to carry out its functions. It is configured as two systems (Main and Redundant) in hot redundant configuration. One system can be selected at a time for control to provide the required outputs. The selected system acts as the MIL_STD-1553B Bus Controller to initiate data transfers from/to all the subsystems which are on AOCS-MIL-STD-1553B bus.

Attitude and Orbit Control Electronics (AOCE) receives attitude information from various attitude sensors, does the processing in accordance with the control algorithms and the chosen mode of operation and generates the control signals for the actuators. AOCE interfaces with attitude sensors and actuators to carry out the above functions. AOCE also interfaces with Telecommand and Telemetry (TTC) to receive the commands and provide health monitoring. It also incorporates mission specific autonomy for spacecraft operations. It has several safety features like Safe Mode logic, Long Pulse Detection, remote programming, and Fault detection and isolation logics.

Table – 11.1: AOCS Equipment list

S.No.	Equipment	Qty.	Remarks
1.	Attitude and Orbit Control Electronics (AOCE)	2	Main and Redundant packages
Sensors			
2.	Coarse Analog Sun Sensor (CASS)	2	Consists of total of eight optical heads. CASS#1 : Conventional CASS with 1553 i/f CASS#2: Micro CASS with 1553 i/f
3.	2-axis Active Pixel Sun Sensor (APSS)	2	Mounted on the spacecraft South face for usage in T.O. only.
4.	Solar Panel Sun Sensors (SPSS)	4	SPSS-N: Main & Redt on North Panel SPSS-S: Main & Redt on South Panel
5.	Earth Sensor (ES)	2	Linear Pitch Range of ±8.96°
6.	Inertial Reference Unit (IRU) consisting of 3 Nos. of DTGs mounted in orthogonal configuration including DTG Rebalance Electronics	1	Provides redundancy in all three axis
7.	Ceramic Servo Acceleometer Package (CSAP) : mounted in tetrad configuration	4	Provides acceleration in all three axes
8.	Star Sensor	4	4 Camera Head Units (CHU) and 2 Attitude Processing Units (APU)
Actuators			
9.	Momentum Wheels (MW)	2	RCD Wheels
10.	Reaction Wheel (RW)	1	
11.	a. Wheel Drive Electronics (WDE) b. Wheel Interface Module (WIM)	3 3	Separate module for each wheel For RCD-make wheels
12.	Solar Array Drive Mechanism	2	Redundant Motor windings with built-in redundant Drive Electronics
13.	Magnetic Torquer	2	350 Am^2 rating
14.	Thrusters	16	East/West are 10N and North/South/Anti-Yaw are 22N
15.	LAM (440N) – 250 Area ratio	1	Used for orbit raising
RF Tracking			

16.	Antenna Pointing Mechanism	4	Independent control of Azimuth and Elevation of 4 Antennae
17.	RF Tracking System + Tracking Receiver RT Card	2	Provide 1553 i/f to AOCE for RF Tracking System

11.3.3 Sensors

GSAT-11 spacecraft carries different types of sensors. They are Star Sensors, Sun sensors, Earth sensors, Inertial Reference Unit (IRU) based on DTG and RF sensor for Antennae control. An Accelerometer has been provided for the delta V (velocity change) measurement during LAM and SK maneuvers. All the sensors except IRU and accelerometer, provide attitude data in the form of absolute attitude. IRU provides the attitude rates as well as incremental angles about all the threee axes. Accelerometer gives the incremental velocity change when the spacecraft experiences the acceleration due to the thruster or LAM firing. The Earth sensor provides pitch and roll attitude for On-orbit control. The Sun sensors include CASS, two-axis APSS and SPSS.

11.3.4 Actuators

AOCE has capability to drive 16 thrusters which are mounted on the spacecraft. The thrusters (total 8 numbers) mounted on East and West face of the spacecraft have 10N capacity; those mounted on Anti-Earth View, North and South face of the spacecrafts (total 8 numbers) are of 22N capacity. All these thrusters provide Attitude and Orbit Control capability during the various phases of the Mission, i.e. Transfer orbit, Orbit raising, Station Acquisition and Station Keeping as well as for Momentum unloading in the Normal on-orbit wheel control mode. Redundant valve coil drivers are provided for the Attitude Control thrusters as well as for the Liquid Apogee Motor (LAM). Each driver is capable of driving both the fuel and oxidizer valves. These 16 thrusters are divided into two blocks,

Block 1: E1, E2, W1, W2, S1, S2, AY1, and AY2

Block 2:E3, E4, W3, W4, N3, N4, AY3, and AY4

Both blocks can be driven by either AOCE1 or AOCE2. The anti-yaw thrusters AY1, AY2, AY3, and AY4 are primarily used for attitude control during LAM firing for Pitch and Roll control. The East/West thrusters provide capability for Yaw attitude control. In the event of failure of AY1 or AY2, the thrusters S1 and N4 can also be used. The anti-yaw thruster firing will augment LAM but with reduced ISP.

The On-orbit mode of control is provided by two momentum wheels and one reaction wheel. The momentum wheels have their angular momentum canted with respect to the negative pitch axis in the pitch-yaw plane. The Transverse momentum wheel is mounted along the yaw axis and is

capable of both clockwise as well as anti-clockwise rotation. The system operates with any two of the three wheels.

Two Momentum wheels are sized with an angular momentum of 68NMS at 6000 rpm and transverse momentum wheel with an angular momentum of 23 NMS at 6000 rpm. The mounting configuration is as shown in Fig. 11.3.

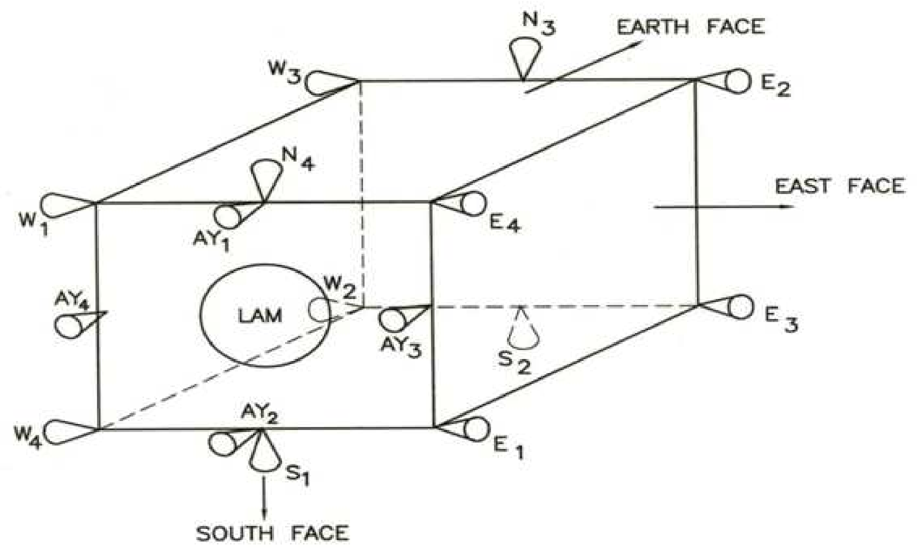


Figure – 11.2: Thruster Configuration

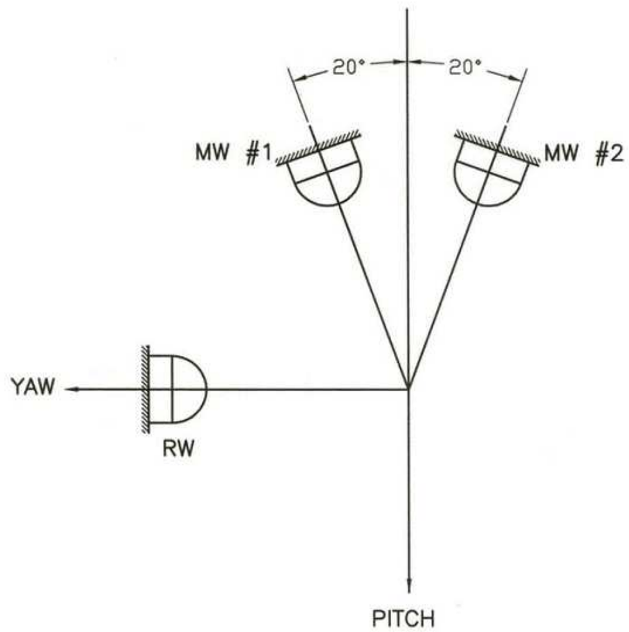


Figure – 11.3: Wheels Mounting Configuration

Magnetic Torquers

The Spacecraft uses two numbers of Permendeur core Magnetic Torquers, each with 350 Am^2 rating to provide continuous de-saturation of the roll/yaw angular momentum and fine yaw control.

Solar Array Drive Assembly (SADA)

GSAT-11 SADA is the latest generation solar array drive assembly developed for driving larger sized solar arrays. This mechanism is capable of driving large sized arrays upto 750kgm^2 inertia and transferring 300A and 21KW power at a bus voltage of 70V. GSAT-11 uses two Solar Array Drive Assemblies (SADA), one for North and the other for south solar array slewing. There are total 60 power slip rings, 30 each for live and return channels to transfer the power from the rotating solar panels to the spacecraft power system. Each power slip ring is provided with 4 wires. The recommended current transfer is 10A/circuit in vacuum. The signal slip ring consists of 50 rings and it transfers the signal across the panels and spacecraft packages and signal slip rings are rated for 2.5A (4 nos.) and 1A (46 nos.).

The new FPGA based Unified Solar Array Drive Electronics with MIL-STD-1553B interface is used for GSAT-11 Spacecraft.

Drives for Antennae Pointing Mechanisms

GSAT-11 has 4 antennae for (16 x 2) spot beams. The use of spot beam requires precise pointing (better than 0.05°) of onboard antenna. This can be achieved by providing a separate RF tracking system for each antenna along roll and pitch axes by independent stepper motors. The onboard tracking system will track the Beacon carrier transmitted by ground station.

The onboard tracking system generates the error signal and accordingly drive signals will be given by antenna drive electronics (ADE) to deployment pointing mechanisms for antenna Pitch and Roll motion to nullify the errors.

11.3.5 MIL-STD-1553 interface

GSAT-11 spacecraft is configured with Dual 1553B buses, AOCE bus and TC bus. Table 11.1 & 11.2 provide the details of the Remote Terminals on AOCE bus and the TC bus. Figure 11.4 gives the block diagram of Mil-std-1553B configuration of GSAT-11.

Table – 11.2: RTs on AOCE bus

Sl No	Subsystem	o. of RTs	of active RTs	T Addresses
1.	TC (TC1, TC2)	2	2	E, F
2.	TM (TM1,TM2)	2	2	6, 7
3.	AOCE-Non Selected	1	1	11 H
4.	DTG (DTG-1, DTG-2 & DTG-3)	3	3	1, 2, 3
5.	Star Sensor (SS1, SS2)	2	2	5, A
6.	NIN (NIN-10 & NIN-20)	2	2	16H, 1AH
7.	ES (ES-1, ES-2)	2	2	18H, 19H
8.	APSS (APSS-1, APSS-2)	2	2	1B H, 1C H
9.	SADA- North (M & R)	2	1	09 H, 0B H
10.	SADA – South (M & R)	2	1	1Eh, 0Ch
11.	CSAP	1	1	04 H
12.	TRRT	2	1	1D
	Total	***23***	***20***	

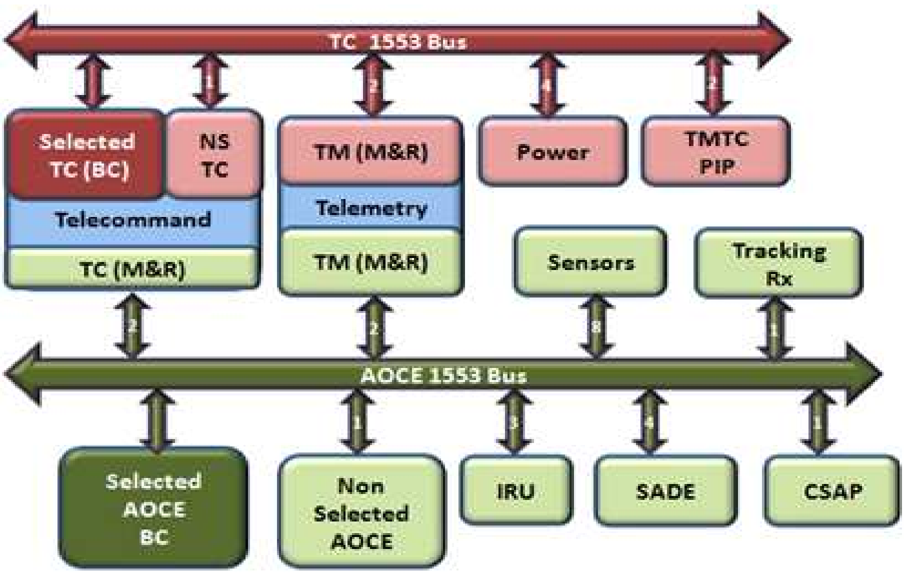


Figure – 11.4: Block diagram of Mil-Std-1553B Configuration

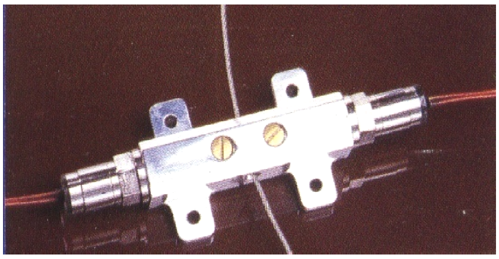
12 Pyros

GSAT 11 incorporates the following pyros :

- ✓ **Pyro cutter:** 8 nos. Solar panel deployment.
  4 nos. Antenna deployment
- ✓ **Pyro valve NC type**: 4 nos. - LAM Pressurant /fuel Oxidizer lines.
- ✓ **Pyro valve NO type:** 2 nos. – LAM Isolation.

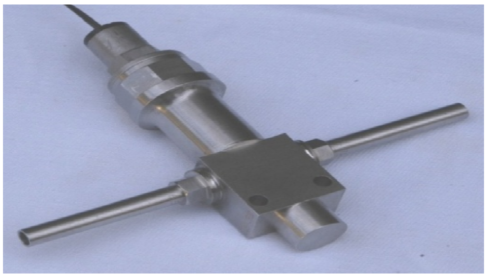
CABLE CUTTER:

No change in design for GSAT-11 Mission .It has a good flight heritage with 183 nos. of on orbit deployments completed, recently was used in GSAT-19 mission.



PYRO VALVE NC Type:

No change in design for GSAT-11 Mission recently was used in GSAT-19 mission.



PYRO VALVE NO Type:

No change in design for GSAT-11 Mission recently was used in GSAT-19 mission.

13 Assembly Integration and Testing

13.1 Introduction

Assembly, Integration and Testing of the Spacecraft will be carried out as per the approved set of documents. EMI/ EMC/ESD control plans, overall grounding scheme for the spacecraft, the design of Electrical distribution system (EDS) will be carried out. In addition, MGSE, EGSE are to be designed and delivered specific for each project.

The Insert Layout Drawing for each of the equipment deck / component on the spacecraft structure is prepared as per the subsystem requirement. Figures – 12.1 to Figures – 12.18 gives the ILDs of equipment panels/structural decks.

Comprehensive Alignment plan for the overall spacecraft is formulated and the same is required to be executed.

Based on the earlier experiences gained from INSAT 3 series and INSAT-4A/4B satellites, the entire AIT operations are divided into five different phases:

13.2 Phase - 1 Activities

During this phase, propulsion subassemblies are integrated onto the Spacecraft structure. This includes assembly of tanks, thrusters, component modules, pyro valves, pressure sensors etc. All the thrusters including the hardware required are welded after aligning them to the required accuracy. Thermal operations on propulsion and structure elements like heaters, temperature sensors and MLI blankets will be carried out. Pressure hold tests are carried out before clearing the structure for further operations.

13.3 Phase - 2 Activities

In this phase, mainly, the main frame subsystems are integrated on to the Spacecraft and tested. The desired sequence of the integration for the subsystems is power, Telemetry, Tele-command, TTC-RF, Control electronics, SADA, Sensors and Wheels.

Payload systems are distributed on North, South and EV panels. Payload sub-assemblies are integrated on North & South flight decks and EV dummy deck. Integrated payload tests are

conducted at SAC, Ahmedabad and transported to ISAC. After delivery, the packages that are on the dummy are transferred onto the actual panels. After the transfer of these subsystems, a detailed test is conducted on payload systems.

A detailed test of all the systems, in this semi - assembled condition, is carried out prior to the assembly of the panels on to the structure. During this test, the equipment panels are electrically interconnected using test harness. This test provides opportunity for establishing the conversion factors, gain verses command details, and to resolve, if any, interface problems.

After successful semi- assembled test, the panels are assembled to the structure. This integrated spacecraft is tested in detail in all the intended modes, which becomes the reference levels for all parameters.

13.4 Phase – 3 Activities

Thermal vacuum tests are performed on the integrated spacecraft in the CATVAC chamber. To drive the package temperatures to the desired values, external heaters and IR lamps are used in addition to onboard heaters.

13.5 Phase - 4 Activities

All the appendages viz. Solar array, deployable antennae etc. will be assembled onto the spacecraft along with feed network. Deployment tests are carried on solar array and antennae using Zero-G facility. Final antennae alignment will be carried out. LAM alignment, welding and testing will be done subsequent to assembly of appendages. Antennae radiation pattern measurements, at spacecraft level, will be done using compact range test facility.

13.5.1 Physical Parameters Test

This test includes the measurement of weight, center of gravity, moment of inertia and static unbalance. Sensors, gyros, wheels, antennae will be aligned w.r.t Spacecraft axis as per the alignment plan. Provision must exist in these subsystems for easy misalignment correction. Depending upon the location of subsystems and alignment requirements cut outs on the spacecraft structure are provided.

13.5.2 Dynamic Tests

Dynamic tests (Sine) or/and acoustic tests are carried out to qualify/verify the spacecraft for mechanical integrity and for launch loads. The spacecraft configuration will be as per the relevant document.

13.5.3 Transportation to Launch Base

The fully integrated and tested spacecraft will be transported to the launch base in the S/C transportation container, specially designed to protect S/C against environmental loads, dust and moisture etc.

13.6 Phase - 5 Activities (Pre - Launch Activities)

Pre-launch activities as per relevant document will be carried out at the launch base. The sequence of operations generally remains same as done in earlier Spacecraft. Suitable modifications in the pre-launch operation plan will be carried out based on launcher, launch-base, co-passenger, availability of time, and other requirements.

14 Mission

14.1 Introduction

Mission operations include the operations during the mission life starting from pre-launch phase. These operations will have to be done according to well thought out predetermined plan. Failure modes and recovery procedures are to be analysed in advance, to the extent possible, so as to avoid irrecoverable loss of spacecraft in contingencies. Realising the need for such pre-planned documentation, the following set of documents are planned to be prepared.

These documents essentially cover different operations that will be carried out during the mission life. The following mission documents have to be tested, evaluated and made available for mission operations during pre-launch phase.

1. Sequence of events
2. Flight control procedures
3. Contingency recovery procedures
4. Telecommand directory
5. Parameter directory
6. Pre-launch simulations plan
7. Normal phase operations plan
8. Mission scenario test procedures
9. Flight Dynamics Software Systems
10. Real time software systems
11. Health processing schemes

14.2 Mission phases and operation

GSAT-11 mission has six distinct operational phases as explained below.

14.2.1 Pre-launch phase

Pre-launch phase is the period prior to launch wherein the readiness for mission operations including mission software and hardware elements, and ground segments are evaluated and ascertained. The pre-launch phase operations essentially aim at ensuring the readiness of all the mission software and

hardware elements. This phase starts once the ground segment is integrated, tested out and are ready for simulation exercises. The main activities in this phase are simulation and training. During this phase all the mission operations and their interfaces are evaluated and also operator familiarisation is carried out to bring the total systems ready for the ensuing launch.

14.2.2 Launch phase

This phase is from lift off till injection into transfer orbit along with re-orientation and separation. During this phase the propulsion line venting also takes place.

14.2.3 Transfer orbit phase

This phase is from injection till the end of first burn of AMF. The main activities are south sun acquisition, earth acquisition, gyro calibration and AMF. Orbit determination and optimisation of the first burn are the other major activities.

14.2.4 Intermediate orbit phase

This phase is from the end of first burn to the completion of apogee motor maneuvers. Ranging and orbit determination, 2nd/3rd AMF optimization are the primary activities. Sun acquisition, earth acquisition, gyro calibration and attitude holding during second and third burn are other related major activities.

14.2.5 Drift orbit phase

This phase is from the completion of LAM firing till station arrival. Deployment of Solar panels and antenna reflector, three-axis stabilization with wheels in loop, and station acquisition maneuvers are the major activities planned in this phase.

14.2.6 Synchronous orbit phase

This phase starts from station arrival and continues till the end of operational life of spacecraft. The last operation may be clearing the S/C from the slot through a de-orbit maneuver. North-South and East-West station keeping and Eclipse operations are the main events along with normal payload operations.

GSAT-11 Spacecraft configuration, based on I-6k bus is compatible with Ariane-5 and other commercially available launch vehicles.

14.3 Launch and Injection

The mission profile of GSAT-11 Spacecraft is in general similar to INSAT-3/4 series.

14.4 Mission Aspect

The major activities involved in the mission are:

- Pre launch simulation (activities at Launch pad and control center)
- Network support verification and rehearsals.
- Launch pad activity (Spacecraft initialization before launch)
- Satellite signal acquisition & Transfer orbit operation
- Orbit raising
- Deployments of appendages
- Wheel turn ON and 3 axis stabilization
- Payload turn on and in-orbit tests.
- On-orbit attitude and orbital maintenance throughout the mission life.
- Inclined orbit operation.
- Orbital repositioning (If required).

The spacecraft is maintained in sun-pointing mode with a slow rate about the sun-pointing axis (pitch axis) unless otherwise orientation change is necessary. During this earth acquisition period (sufficiently prior to Apogee in AMF orbit) gyro calibration is carried out and the spacecraft is then re-oriented for AMF attitude (inclined axis holding) about 45 minutes prior to the commencement of AMF burn. All the three axes are held by GYROS.

The configuration of GSAT-19 allows verifying the LAM attitude using APSS/CASS/SPSS after LAM reorientation.

After the first AMF, the spacecraft enters in to an Intermediate Orbit (IO). Nominally the spacecraft lasts in IO for one orbit, primarily to establish the orbit to the required accuracy.During the IO phase, principle activities are to collect orbit data, carry out health checks and to prepare for the eclipse operations if any. The spacecraft ismaintained in sun-pointing mode with a slow spin about the pointing axis for mostof the time. The second AMF is optimized based on the performance of first AMFand resulting IO.

After one IO, Earth pointing and GYRO calibrations are carried out prior toapogee #4 and the second AMF is carried out near apogee #4.The third AMF is for a very short duration and occurs in next IO. The spacecraftis expected to be near the stations but at westward longitude and the

orbitbecomes nearly synchronous. The spacecraft moves with a very small residualdrift rate towards the station.

The deployment of the North and South Solar Panels, West and East reflectorsand three axes stabilization is carried out at this stage. Further orbit trimming manoeuvres like circularisation, residual inclination corrections are carried out in this phase. Finally, a small westward correction is imparted at the perigee to acquire station and to arrest the drift. After spacecraft arrival on-station, in-orbit performance testing of the payload begins.

The spacecraft is maintained On-station by carrying out periodic E-W and N-S station keeping maneuvers. The other important operations in the on-orbit phase are station keeping, eclipse operations and Sun-outage planning. There may be a repositioning maneuver required during the mission life. Towards the end of the operational lifetime of the spacecraft, a de-orbiting operation is carried out to vacate the parking slot in order to keep the geo stationary ring clean.

15 Launch Vehicle

15.1 Introduction

GSAT-11 is scheduled to be launched on-board Ariane 5. Typical Ariane 5 GTO parameters are given below:

Inclination	:	< 6 deg
Apogee Altitude at first apogee	:	~36000 km
Perigee Altitude	:	> 250 km
Argument of Perigee	:	178 deg
Longitude of Ascending node	:	-122 deg

15.2 LAUNCH VEHICLE INTERFACE

15.2.1 Mechanical Interfaces

The spacecraft is mated to the launch vehicle payload adaptor with the standard dia.1194mm interface. The upper part of the adaptor has the interface with the spacecraft. The lower part of this adaptor has interface with the upper stage of the launch vehicle.

15.2.2 Electrical Interfaces

The electrical interface is made of two umbilical links coming from the spacecraft umbilical connectors to the electrical umbilical plug. The electrical links have to be finalized with mutual agreement with the launcher agency.

16 Spacecraft Budgets:

16.1 Power budget:

GSAT11 Power Budget						
Sl.No	**Subsystem**	**LP**	**TO**	**Equinox**	**SS**	**Eclipse**
1	Power	66.0	66.0	66.0	66.0	66.0
2	Core TMTC-10 & 20	62.0	62.0	62.0	62.0	62.0
3	TMTC PIP-10	12.0	12.0	12.0	12.0	12.0
4	TMTC PIP - 20	12.0	12.0	12.0	12.0	12.0
5	TTC Rx-1 & 2	24.0	24.0	24.0	24.0	24.0
6	TTC Tx (high power mode)	30.0	60.0	0.0	0.0	0.0
7	TTC Tx (Low Power mode)	0.0	0.0	24.0	24.0	24.0
	UBUS Total	**206.0**	**236.0**	**200.0**	**200.0**	**200.0**
8	Sel AOCE + Mag torquer	15.4	19.0	34.0	34.0	34.0
9	Non sel AOCE	15.4	15.4	15.4	15.4	15.4
10	LAM firing + Att thrusters*	0.0	97.2	0.0	0.0	0.0
11	Antenna Drive Electronics (ADE-10&20)	0.0	0.0	34.7	34.7	34.7
12	TRRT	0.0	0.0	1.2	1.2	1.2
13	ES-1	0.0	5.4	5.4	5.4	5.4
	ES-2	0.0	5.4	0.0	0.0	0.0
14	APSS- 1	0.0	4.5	0.0	0.0	0.0
	APSS-2	0.0	4.5	0.0	0.0	0.0
	NIN-10 (M)	7.0	7.0	7.0	7.0	7.0
15	NIN-10 ®	7.0	7.0	7.0	7.0	7.0
16	Star Sensor	0.0	31.2	31.2	31.2	31.2
	DTG1	25.0	25.0	25.0	25.0	25.0
	DTG2	25.0	25.0	25.0	25.0	25.0
18	DTG3	25.0	0.0	0.0	0.0	0.0
19	wheels + WDC + WIM + WDE	0.0	0.0	78.0	78.0	78.0
20	SADA (Motor + electronics)	0.0	0.0	30.0	30.0	30.0
21	CSAP	25.0	25.0	25.0	25.0	25.0
23	Thermal @60% dutycycle	150.0	905.0	370.9	319.2	339.0
24	Battery Charging	0.0	0.0	1000.0	0.0	0.0
25	Integration (1%)	7.07	16.5	20.9	10.4	10.6
26	Mainframe Load	507.9	1429.1	1910.7	848.5	868.5

27	Payloads (with 3dB OBO)	0.0	0.0	7300.0	7300.0	7300.0
28	**Total Power Requirement**	**507.9**	**1429.1**	**9210.7**	**8148.5**	**8168.5**
29	**Power Generation (EOL)**		**1560.0**	**13614.0**	**12070.0**	
30	**Margin#**		**130.9**	**4403.3**	**3921.5**	
31	**One String Failure**			**415.0**	**415.0**	
32	Margin with 1 string failure and Battery Charging			3988.3	3506.5	
33	Margin with 1 cell failure					
34	Battery DOD %					50.5
35	Battery DOD % with 1 cell failure					54.5

16.2 Mass Budget:

SL.NO	CODE	DESCRIPTION	MASS
1	PAL	COMMUNICATION PAYLOAD	646.5
2	POW	POWER SYSTEMS	492.2
3	TMC	TELEMETRY AND TELECOMMAND	65.0
4	TRF	TTC-RF SYSTEMS	15.0
5	AOC	ATTITUDE CONTROL ELECTRONICS	67.2
6	INS	INERTIAL SYSTEMS	65.4
7	SEN	SENSORS	17.4
8	STR	STRUCTURE	426.7
9	TCS	THERMAL CONTROL SYSTEMS	235.9
10	MSM	MECHANSIMS	110.0
11	PRO	PROPULSION SYSTEM	198.3
12	AIT	ASSEMBLY, INTEGRATION & TESTING	231.1
13	TDM	TOTAL DRY MASS	2570.5
14	DMM	MARGIN	3.0
15	**SDM**	**SPACECRAFT DRY MASS**	**2573.5**
16	PRO	PROPELLANT	3194.0
17	POX	OXIDISER	1988.7
18	PFU	FUEL	1205.3
19	PRE	PRESSURANT	8.0
20	**LOM**	**LIFT-OFF MASS**	**5775**

17 Heritage Matrix:

Table 16.1 Bus system heritage matrix

SUBSYSTEM/ COMPONENT	HERITAGE	MANUFACTURER	TYPE OF CHANGE	TEST LEVEL	REMARKS
Structure	New	ISRO through HAL	-	Static qualification done with flight the structure, dynamic qualification will be done for PFM levels	All the joints are similar to standard I-3K structure, except cylinder to cylinder joint, which is qualified through static and dynamic test.
MECHANISM					
Solar Array Deployment	INSAT-3/4 & GSAT Series	ISRO	NIL	FM	-
Antenna Deployment	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
Thermal					
Thermal Equipment panel with Heat pipe	INSAT-3/4 & GSAT Series	ISRO	NIL	FM (s/c)	Heat pipes /heaters /temperature sensors/MLI/osr/ black tape etc. are all identical to earlier satellites.

Thermal Design implementation	INSAT-3/4 & GSAT Series	ISRO	NIL	FM (s/c)	Implementation process is same as earlier missions
AOCS					
Attitude and Orbit Control Electronics	GSAT-19	ISRO	Honeywell processor in place of MAR31750 processor used in GSAT-19	FM	QM developed under GSAT-19, Honeywell processor heritage is derived from GSAT-17 and INSAT-3DR
Antenna Drive Electronics	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
Wheel & Wheel drive electronics	INSAT-3/4 & GSAT series	Rockwell Collins	NIL	FM	Same as previous missions.
Wheel interface module	New	ISRO	-	FM +QM	Interface card is changed wrt GSAT series packages
SADA Mechanisms north & South	New	ISRO	NIL	QM+ FM	Stepper motor, gear system, signal slipring assembly, contact material and lubrication have heritage from earlier

					GSATs
SADA Electronics	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
Magnetic Torquer	INSAT-3/4 & GSAT series,	ISRO	NIL	FM	-
IRU	GSAT-19, IRNSS, INSAT-3D	ISRO	70V DC-DC is a change wrt IRNSS and INSAT-3D, No change wrt GSAT-19	FM	-
Ceramic Servo Accelerometer	New	ISRO	-	QM + FM	Similar package was flown in chandrayyan-1
Earth Sensor	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
Sun Sensors: SPSS CASS	INSAT-3/4 & GSAT series	ISRO	NIL	FM	-
Micro-CASS	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
APSS	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
Sensor Electronics	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
Mark-3 Star	GSAT-19	ISRO	NIL	FM	QM developed

Sensor					under GSAT-19
Power System					
Solar Panel Substrates	New	ISRO/M/S TAML	NIL	FM + QM	Changes wrt curing process, Qualified on coupon and QM panel
Solar Cells: (Multi Junction Cells)	GSAT series	M/S Emcore, USA	Gold flash on interconnection is new. Qualified on coupon and QM panel	FM	-
Core POWER Electronics	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
Battery discharge regulator	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
Shunt package	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
Magnetic current sensor	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
Electro explosive devises package	GSAT series	ISRO	NIL	FM	-
Bus Bar	Similar type is used in Uro-	AXON	NIL	FM +QM	QM is done by vendor and

	Star-3 platform				passed through all qualification
Fuse distribution module	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
DC/DC converters	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
BATTERY	GSAT-16, 18 and W2M	Battery assembly by ISRO / Cells from SAFT VES, France	NIL	FM	-
TELEMETRY AND TELECOMMAND					
TTC Base band	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
Telemetry Transmitter	IRNSS Series , GSAT-19	ISRO	Change in DC-DC convertor and interface card wrt IRNSS, no change wrt to GSAT-19	FM	Frequency specific to project, incremental QM developed under GSAT-19 for both
Telecommand Receiver	IRNSS Series , GSAT-19	ISRO	Change in DC-DC convertor and interface card wrt IRNSS, no change wrt to GSAT-19	FM	

TTC Antenna	INSAT-3/4 & GSAT series	ISRO	NIL	FM	-
PROPULSION SYSTEM					
Configuration: Bi-propellant system	INSAT-3/4 & GSAT series	ISRO	NIL	FM	-
Propellant tanks (2 nos.)	Space Bus family	Astrium (airbus)	-	FM	Tanks from same vendor have been used in earlier GSAT series.
Pressurant tanks (3 nos.)	Chandrayaan-1, MOM and IRNSS series	ATK	NIL	FM	-
Pressure Transducers	INSAT-3/4 & GSAT series	ISRO	NIL	FM	-
LAM	INSAT-3/4 & GSAT series	ISRO	solenoid coil redesigned to operate at 70V, keeping mechanical elements same as earlier GSATs	FM	QM developed under GSAT-19
AOCS Thrusters: 22N and 10N	INSAT-3/4 & GSAT series	ISRO	Change in 70V downstream valves, keeping	FM	QM developed under GSAT-19

			mechanical elements same as earlier GSATs		
Other propulsion elements like CHECK VALVE, FILL & Drain valve, pressure regulators etc.	INSAT-3/4 & GSAT series	ISRO	NIL	FM	-
Latch valve GAS	INSAT-3/4 & GSAT series	ISRO	NIL	FM	-
Single flow latch valves	GSAT-19	ISRO	NIL	FM	QM developed under GSAT-19
PYROS					
Cable cutters, Normally Closed and Normally Open pyros	INSAT-3/4 & GSAT series	ISRO	NIL	FM	-

Note:

1. GSAT-19 spacecraft launched successfully, functionality of the packages has been verified On-orbit, no anomaly observed.
2. GSAT Series of spacecrafts: GSAT-4, GSAT-6, GSAT-7, GSAT-8, GSAT-9, GSAT-10, GSAT-12, GSAT-15, GSAT-16, GSAT-17, GSAT-18.
3. INSAT Series of spacecrafts: INSAT-3A, INSAT-3B, INSAT-3C, INSAT-3D, INSAT-3E, INSAT-4A, INSAT-4B, INSAT-4CR.
4. IRNSS series of spacecrafts: IRNSS-1A, IRNSS-1B, IRNSS-1C, IRNSS-1D, IRNSS-1E, IRNSS-1F, IRNSS-1G

Table 16.2 Payload system heritage matrix

LNA &Frequency Converters					
Sr. No.	**Payload Element**	**Heritage**	**Manufacturer**	**Test Level**	**Remark**
1	Ku Band LNA	GSAT-19	Astra Microwaves Pvt Ltd (AMPL)	FM	QM developed under GSAT-19
2	Ka Band LNA	GSAT-19	Komoline Aerospace Ltd (KAL) + SAC	FM	
3	Ka to Ku D/C (OCXO based)	GSAT-19	KAL + SAC	FM	
4	Ku to Ka band U/C	GSAT-19	KAL + SAC	FM	
5	Ku x IF D/C	GSAT-19	SAC	FM	
6	Ka x Ku LO Source Type-1 , 2	GSAT-19	SAC	FM	
7	Ku x IF LO Source	GSAT-19	SAC	FM	
8	Ku to Ku U/C (Type-1 & 2)	GSAT-19	SAC	FM	
Driver Amplifiers & TWTAs					
Sr. No.	**Payload Element**	**Heritage**	**Manufacturer**	**Test Level**	**Remarks**

1	Ku Band DA	G-16 , 18	Centum	FM	
2	Ku 150W LTWTA	Thor 5 (2R), Asiasat 5 Optus D1-D3, AMOS4, EchoStar-14,Intelsat-14, Asiasat 5, GSAT-8/ 10/ 15/16/18/ 19	L3- Comm, USA	PFM +FM	Qualified in 2005
3	Ka Band 130 LCTWTA	Telstar-8, Wildblue-1, Echostar-9, IPSTAR,YAHSAT-1B, KaSAT-T1/T2, HMS Jupiter, GSAT-19	Thales, France	PFM + FM	Qualified in 2003

Beacon Assemblies					
Sr. No.	**Payload Element**	**Heritage**	**Manufacturer**	**Test Level**	**Remark**
1	Ku-Beacon Source	GSAT-7/ 8/10/15/16/ 17/19	SAC	FM	
2	Ka-Beacon Source	GSAT-19	SAC	FM	QM developed under GSAT-19
3	Ku-Beacon SSPA	GSAT-19	SAC	FM	

4	Ka-Beacon SSPA	GSAT-19	SAC	FM	

Tracking System

Sr. No.	Payload Element	Heritage	Manufacturer	Test Level	Remark
1	Tracking System Switch matrix	GSAT-19	SAC	FM	QM developed under GSAT-19
2	2 Channel Tracking Receiver	GSAT-19	SAC	FM	

EPCs

Sr. No.	Payload Element	Heritage	Manufacturer	Test Level	Remark
1	Ku &Ka-band LNAs (Dual assembly)	GSAT-19	Centum	FM	QM developed under GSAT-19
2	Frequency Converters	GSAT-19	Centum	FM	
3	Tracking Receiver	GSAT-19	Centum	FM	
4	OCXO Distribution Network	GSAT-19	Centum	FM	
5	Ku-band Beacon Source & SSPA	GSAT-19	Centum	FM	

6	Ka-bandBeacon Source & SSPA	GSAT-19	Centum	FM	

Antenna & Feeds					
Sr. No.	**Payload Element**	**Heritage**	**Manufacturer**	**Test Level**	
1	Ku-MBA Feed	GSAT-19	ATIRA + SAC	PFM	QM developed under GSAT-19
2	Ku-band MBA Reflector	INSAT-4CR/ GSAT-14/ 19	CMSE, VSSC	FM	
3	Ka-band Feed chains	GSAT-19	SAC	FM	
4	Ka-band Tx/Rx Diplexer	GSAT-19	SAC	FM	
5	Ka-band MBA Reflector	INSAT-3A, GSAT-18/19	CMSE, VSSC	FM	PFM test in GSAT-19
5	Ku-band Beacon Horn Antenna	GSAT-7/19	SAC	FM	
6	Ka-band Beacon Horn Antenna	GSAT-14/19	SAC	FM	
Ka band Filters					

Sr. No.	Payload Element	Heritage	Manufacturer	Test Level	Remark
1	Ka band Rx Test coupler	GSAT-4, 19	SAC	FM	
2	Ka Band PSF	GSAT-19	SAC	FM	QM developed under GSAT-19
3	Ka Band Hybrid	GSAT-19	SAC	FM	
4	Ka band I/P Filter	GSAT-4	SAC	FM	PFM test in GSAT-19
5	Ka band O/P filter	GSAT-4	SAC	FM	
6	Ka band HRF	GSAT-19	SAC	FM	QM developed under GSAT-19
7	Ka band PIM	GSAT-19	SAC	FM	
8	Ka band Tx test coupler	GSAT-19	SAC	FM	
9	Ka- Beacon HRF	GSAT-19	SAC	FM	

Ku Band Filter

Sr. No.	Payload Element	Heritage	Manufacturer	Test Level	Remark

1	Ku- Band PSF	GSAT-19	SAC	FM	QM developed under GSAT-19
2	Ku I/P filter Assembly (LB)	GSAT-19	SAC	FM	PFM test in GSAT-19
3	Ku I/P filter Assembly (UB)	GSAT-19	SAC	FM	
4	Ku O/P Filter	INSAT-4CR	SAC	FM	
5	Ku band HRF	GSAT-19	SAC	FM	QM developed under GSAT-19
6	Ku-Band PIM Filter	GSAT-19	SAC	FM	
7	Ku Tx /Rx Diplexer	GSAT-8	SAC	PFM + FM	
8	Ku Tx /Rx Test coupler	GSAT-16/19	SAC	FM	QM developed under GSAT-19
9	Ku band Hybrid	GSAT-19	SAC	FM	
10	Ku-beacon HRF	GSAT-19	SAC	FM	
11	Ku-band narrow filter	GSAT-19	SAC	FM	